

Applying Mobile and Pervasive Computer Technology to Enhance Coordination of Work in an Surgical Ward

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Abstract

Collaboration, coordination, and communication are crucial in maintaining an efficient and smooth flow of work in an operating ward. This coordination, however, often comes at a high price in terms of unsuccessfully trying to get hold of people, disturbing telephone calls, looking for people, and unnecessary stress. To accommodate this situation and to increase the quality of work in operating wards, we have designed a set of pervasive computer systems which supports what we call context-mediated communication and awareness. These systems use large interactive displays, video streaming from key locations, tracking systems, and mobile devices to support social awareness and different types of communication modalities relevant to the current context. In this paper we report qualitative data from a one-year deployment of the system in a local hospital. Overall, this study shows that 75% of the participants strongly agreed that these systems had made their work easier.

Keywords:

Operating Room Information Systems, Awareness, Communication, User-Computer Interface, Software Design, Mobile Phone, Handheld Computers, Computerized Medical Record

Introduction

Ensuring a smooth flow of work in a operating wards requires efficient collaboration, coordination, and communication [1,2]. A considerable amount of time and energy is spent on getting information about where people are located, what they are doing, getting information about changes in plans, and ensuring that the right staff is present inside the operating room at the right time, including the patient. Large whiteboards and a constant flow of phone calls are some of the tools that clinicians use to communicate, to stay aware on the flow of the work, and to maintain a social awareness of one another.

Information posted on whiteboards are, however, only visible in one location. For example, the whiteboard that displays today's operation program is typically only visible from the coordinating central within the operation ward. Similarly, phone calls might be a useful tool for the caller to gain knowledge and coordinate his or her work, but phone calls may also be disturbing to the recipient because they are occupied with other activities [3].

This paper describes a set of pervasive computing systems called iHospital which are designed to support the intense coordination of work in an operating ward. The goal of these systems is to address some of the shortcomings of communication and awareness systems in use today, thereby increasing the quality and efficiency of operation coordination. The paper then reports from qualitative studies of a one-year deployment of the systems which demonstrates that the systems in general made work easier on the wards by helping clinicians to reduce interruptions, locate each other, get an overview of work, coordinate work, handle changes in work, communicate in and out of the operating ward, and to reduce the amount of traffic in and out of the operating room.

Systems Design

The designed system was developed in close participating with doctors and nurses over a one-year period. Several workshops and early mockup and prototypes were used to test out early ideas and get instant feedback. The final developed and deployed system was comprised of three separate but tightly integrated sub-systems: (i) a location tracking system, (ii) the AwareMedia system, and (iii) the AwarePhone system.

Location Tracking

The *location tracking system* was designed to get information about the activities and whereabouts of the clinicians. The location tracking system was a zone-based tracking system that only tracks clinicians inside predefined zones, like operation rooms, the patient wards, and the recovery department. Zone-based tracking was chosen partly due to the high cost of fine-grained indoor location tracking equipment, partly because this coarse-grained location was deemed sufficient for our purpose, and partly due to privacy protection of clinicians once outside of 'interesting' zones (see [4] for a survey of tracking systems ubiquitous computing). Clinicians were only tracked inside predefined zones and no logging was performed about how much time the clinicians spent in different zones.

In the pilot study, location tracking was done by tracing Bluetooth tags and devices (e.g. mobile phones) worn by clinicians. Location information was displayed in the AwareMedia and AwarePhone systems.

AwareMedia

AwareMedia is a full-screen, touch sensitive system running on large and medium-sized wall displays. These clients are typically deployed in the coordination central of an operating ward, inside each operating room, in different patient wards, and in the recovery ward. *AwareMedia* presents an overview of what is going on in relation to the daily handling of surgeries. The display shows a list of operation rooms and a list of people at work, where they are located, and what their current schedule, according to their calendar.

AwareMedia displays a detailed view of the current and scheduled activities inside each operating room. It displays the current operation, its status, the people located by the tracking system inside the room, the patient being tracked, and a complete schedule of the surgeries scheduled for this room. This information provides an overview of the status and activities inside each operating room as well as detailed and updated information about the clinicians associated with the operating ward.

The program not only provides an overview of what is going on, it also supports different types of communication. A video link from each operating room provides a passive overview of what is going on in each operating room (these video links are also called media spaces [5]). The quality is adjusted so it provides an overview of what is going on the operating room without being privacy-invading for the patient. A chat function allows clinicians to send information between the system and the operating theatres, collaborating wards or mobile devices running the *AwarePhone* system.



Figure 1 The *AwareMedia* System running on two large displays in use at the hospital (left), The *AwarePhone* System displaying a list of clinicians and their location (bottom) and at the top is a clinician wearing a small tracked Bluetooth chip (top).

AwarePhone

The *AwarePhone* system is an application running on mobile devices and it provides a similar functionality to the *AwareMedia* system. The mobile device has a smart phone book where each clinician and operating room is listed. Besides presenting the name the phone book keeps an updated list of the location of clinicians, their current booking in the calendar system and a self-reported status. Next to the operating rooms is listed the current surgery in that room and its status (patient arrived, surgery just started etc). By selecting a person or an operating room, the system presents the options to call the

person/room or send a message. If a message is sent to the operating room the message is presented to the people in the operating room through the *AwareMedia* system.

Figure 1 shows an overview of the three systems. To the left is the *AwareMedia* system running in the coordinating central at the hospital, to the right is a clinician tracked with a Bluetooth chip, and the bottom picture shows the *AwarePhone* system. The developed systems are rather complex and the technical details of the systems are presented in depth in [6, 7, 8].

Methods

The suite of systems described above was deployed in January 2006 in an operating ward in a medium-sized Danish hospital. The operating ward is a centralized ward with nine operating rooms and supports three departments (organ, orthopedic, and gynecology/obstetric surgery). Around 150 clinicians were associated with the operating department.

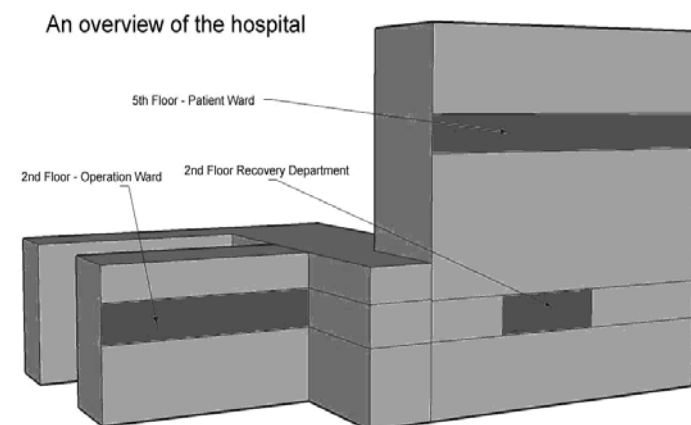


Figure 2: A view of the hospital with the operating ward marked to the left on the second floor, the recovery department in the main building on the second floor and the patient ward at the fifth floor in the main building.

For the pilot study, three operating rooms were equipped with the *AwareMedia* system (two orthopedic and one gynecologic), the coordinating central was equipped with a large wall-sized version of *AwareMedia*, and the recovery department and the patient ward for orthopedic surgery was also equipped with the system. For the tracking system 10 zones were defined and the system was able to track around 30 people (20 carrying mobile devices and 10 carrying tags). 15 mobile phones were distributed to clinicians, operation technicians, and nurses with coordination responsibilities.

Figure 2 shows a sketch of the hospital and presents the areas of the hospitals the system was installed in.

Table 1: The Table shows ten of the forty six questions and the corresponding responses.

How much do you agree with the following statements?	Strongly agree	Agree	Neutral	Slightly disagree	Disagree	Don't know	Not answered
9a. The system has lead to <u>fewer interruptions</u>	35%	30%	14%	0%	7%	12%	2%
9b. It has been easier to <u>locate</u> co-workers	42%	23%	21%	5%	5%	5%	0%
9c. I have a <u>better overview</u> of today's work tasks.	53%	23%	12%	5%	2%	5%	0%
9d. The system made it easier to <u>coordinate</u> work.	47%	21%	14%	0%	5%	5%	9%
9e. I save some <u>steps</u> .	49%	16%	19%	5%	7%	5%	0%
9f. It has become easier to <u>handle changes</u> in today's schedule.	35%	33%	23%	0%	5%	5%	0%
9g. There has been a better communication between <u>the operating ward and the recovery department</u> .	9%	16%	30%	0%	7%	30%	7%
9h. There has been a better communication between <u>the operating ward and the patient ward</u> .	23%	21%	21%	5%	7%	21%	2%
9i. The system has <u>minimized the traffic</u> in and out of the operating rooms.	30%	28%	14%	2%	2%	19%	5%
9j. <u>The patient</u> is getting a better treatment	7%	23%	37%	0%	9%	19%	5%

Results

Questionnaires

Questionnaires were given to a number of clinicians such as operation technicians, nurses, anesthesiologists, and surgeons. In total 43 questionnaires was handed out, 34 responses came from nurses and 9 from doctors and other medical personnel (approximately half the clinician working regularly in the operating ward filled out a questionnaire).

Being asked about the question, if the system in general made their work easier, 75 % strongly agreed with this statement. Only a single response stated that the system made it more difficult to use. Some other results from the questionnaires are presented in Table 1 which reveals that clinicians found that the systems helped them coordinate their work, led to fewer interruptions, helped them locate co-workers, saved them some steps, helped them handle changes in the operating schedule, helped improve communication in and out of the operating ward, and reduced traffic in and out of the operating room. The clinicians, however, reported that they did not find that the systems significantly helped improve patient treatment.

Interviews

Fourteen structured interviews were performed with doctors, nurses and supporting staff after the system had been used for three months. Each interview lasted approximately half an hour each.

The data material is huge, and in this paper we will only present very few of the statements. One of the findings highlighted by several persons was the ability to react to changes earlier than before. An operating nurse puts it this way:

[With the system] people are starting to react earlier than before. We can see the surgery in operating room 9 is delayed

so the last patient can be operated in room 4 instead. And that is a clear advantage because then the surgeon can just throw the gloves and move on to the next patient. That is a huge advantage because sometimes the last patient needed to be postponed to the next day.

By monitoring the progress in the different operating rooms simultaneously, the coordinating nurse has a powerful tool to move patients to other rooms if the schedule is behind in one of the rooms.

Log Data

The system logged all the interaction with the system. From the logged data we were able to analyze how the system was used, how many people that were tracked each day, how many messages sent, and similar data. For instance Figure 3 shows the number of surgeries created, modified, and deleted (canceled) using the system from January to September.

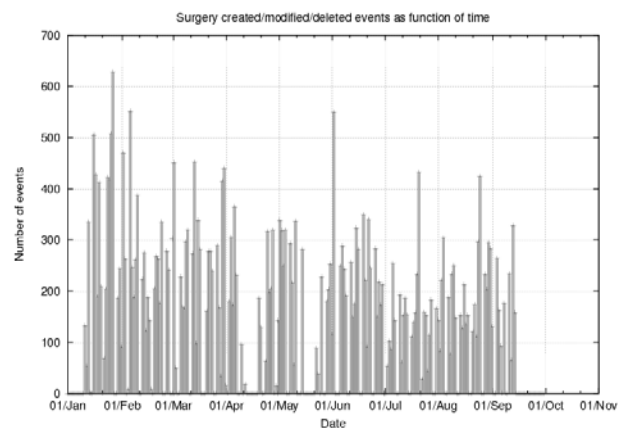


Figure 3: The number of changes made by the AwareMedia system from January to September. A change can be a surgery being moved, a surgery being extended, the personal associated with the surgery being substituted. Some actions might result in a number of changes.

Figure 3 shows that the amount of changes made to the schedule each day is quite substantial – from 100-500 events pr. day, which correspond to approximately 10-20 changes to each operation. A small drop over time can be seen, but our analysis points to this drop being due to the clinicians getting more skilled in using the system and actually not less use. However, a larger drop can be found in the number of users being location tracked which will be further addressed in the discussion.

Discussion

Based on the study of the deployed set of systems, we will argue that there is some evidence that such mobile and pervasive computing systems may help enhance the work in an operating ward.

Efficiency

There is clear evidence that the system increased the efficiency in work at the operating ward. 67% of the clinicians agreed that the systems made coordination easier. 66% found that they could handle changes in the daily operating schedule easier and in the interviews the clinicians argued, that the systems increased the number of performed surgeries because it was easier to coordinate and gather resources to unscheduled surgeries. We are currently working on elaborating the findings by analyzing the number of surgeries carried out before and after the introduction of the systems.

The system was also designed to make communication between the operating ward and the patient ward and recovery ward easier. However, in the questionnaire only 44% and 26% respectively agreed to this. It was nevertheless in the interviews argued by the people using the system a lot¹ that the systems did enhancing cross-departmental communication and coordination. Many clinicians simply did not use this feature of the system, which also explains the large number of ‘don’t knows’ in the questionnaire.

It is evident that the system helps clinicians locate each other and saves them many unnecessary steps. 65% agreed that it was easier to locate people and 65% agree that the systems save them some steps. Hence, critical time is saved.

Finally, the clinicians did not agree with the statement that the treatment of the individual patient had been improved based on the systems. However, the questionnaire was not handed out to people at the recovery and patient ward. At these ward they pointed out that they were able to give much more precise information to the patients and their relatives with the presented system than before. Secondly, the systems directly increase the *work quality* of the clinicians as such and hence indirectly provide better treatment of the patient.

¹ This was typically nurses working as ‘coordinators’, i.e. the person in charge of coordinating the whole operating schedule for the whole operating ward. It was typically this person who was in charge of calling the patient ward and the recovery ward to ensure a smooth in- and out-flow of the patients.

Quality

Too much turbulence in the operating room can bring bacteria close to the surgical area and it is hence important to keep the airflow from the non-sterile areas to a minimum. Opening the door to an operating room in order to pass on a message, for example, is hence a safety hazard. It is hence interesting to note that 58% of the clinicians agreed that traffic in and out of the operating room has been minimized which clearly has improved the hygiene inside the operating rooms.

Especially, the chat messages were used as an alternative to passing messages between the operating room and the rest of the department. These messages were also mentioned as being far less interruptive than e.g. opening the door or calling the room for passing on shorter messages.

In particular from the interviews it became clear that the system could decrease errors or misunderstandings. A number of operation nurses pointed out that a number of misunderstandings previously arose simply because changes to the schedule were not passed on to all involved clinicians. As one of the operating nurses explained in an interview:

“I remember once I was preparing for an operation. After I had finished preparing all the equipment, I was told that the operation was canceled. I had to return the equipment and start all over again, thereby delaying the flow of work. If I have had the system in that operating room it would have saved a lot of time for everybody.”

The nurses saw a significant decrease in these types of errors by using the suggested system.

Finally, we conclude that many of the interviewed clinicians found the system to make the work less stressful and overall strengthen the feeling of being ahead. Findings which are supported by the decrease in interruptions and easing of collaboration and scheduling pointed to by the questionnaires.

Challenges

While the results are promising a number of challenges exist. Interference is a highly controversial and debated area following the introduction of wireless communication technologies in hospitals. In some hospitals wireless equipment are used extensively whereas others have a complete ban on all wireless and mobile communication equipment and little research exists to guide the decisions. For our trial we got a research permit to try out mobile devices in the operation ward though with a safety distance of one meter to older medical equipment. A recently published paper in Mayo Clinic Proceedings concludes based on more than 300 tests that mobile phones do not pose the risk of interference [10].

A related problem with mobile and wireless technology is battery lifetime. While some systems can run for days, others need to be recharged regularly and managing the recharging process can be a burden.

Also privacy and local regulations pose a challenge. While the systems are designed to support quick overview and the ability to gather information by glazing at the displays while walking by, this easy access to information also pose a problem. Regulations are designed to ensure that sensitive information is only viewable by registered users. Logging of all interaction including viewing the data is often a requirement. Balancing

easy to use information overview with the confidentiality of the information displayed is a clear challenge. In the trial we addressed this issue by only placing the displays in restricted areas, but even this approach might not correspond with the regulations in some countries.

Conclusion

The pressure on the health system is increasing. There is a constant demand for treating more patients with new techniques with the same amount of human and financial resources. New types of Ubiquitous Computing systems alleviate this fundamental dilemma by helping staff increase the level of treatment for the same amount of resources. Not by cutting the time spent talking to patients or increasing the overall speed, but by reducing some of the small time consuming problems encountered in everyday medical work. For example, the time spent searching for people, coordinating treatments, passing on information, being interrupted, or waiting for computers to log in [9].

In the presented set of iHospital systems we have found clear indications of how a system designed to support awareness and collaboration with the feedback from clinicians indeed can increase both the efficiency and quality of surgical treatment. The system was designed to run as a prototype for three months and currently it has been running for more than a year and clinicians call it an invaluable tool in their work. At the point of writing a new system is being developed based on the pilot study that is able to support the entire operating ward and collaborating activities.

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