Virtual Video Prototyping of Pervasive Healthcare Systems

Jakob Bardram[α], Claus Bossen[α], Andreas Lykke-Olesen[χ], Kim Halskov Madsen[β], Rune Nielsen[χ]

α : Department of Computer Science
Aarhus University
Aabogade 34
DK 8200 Århus N, Denmark
bardram@daimi.au.dk
bossen@daimi.au.dk

β : Department of Information and Media Studies
Aarhus University
Aabogade 34
DK 8200 Århus N, Denmark
halskov@imv.au.dk

χ : Aarhus School of Architecture
Nørreport 20
DK-8000 Århus C, Denmark
andreas.lykke-olesen@a-aarhus.dk
rune.nielsen@a-aarhus.dk

ABSTRACT

Virtual studio technology enables the mixing of physical and digital 3D objects and thus expands the way of representing design ideas in terms of *virtual video prototypes*, which offers new possibilities for designers by combining elements of prototypes, mock-ups, scenarios, and conventional video. In this article we report our initial experience in the domain of pervasive healthcare with producing virtual video prototypes and using them in a design workshop. Our experience has been predominantly favourable. The production of a virtual video prototype forces the designers to decide very concrete design issues, since one cannot avoid paying attention to the physical, real-world constrains and to details in the usage-interaction between users and technology. From the users' perspective, during our evaluation of the virtual video prototype, we experienced how it enabled users to relate to the practicalities and context of applied technology. One of the main limitations experienced in the creation of the virtual video prototypes is the lack of user-involvement.

Keywords

Prototyping, virtual studio, design, video, pervasive computing, pervasive health care

INTRODUCTION

Based on extensive studies of design processes within various disciplines, Schön has identified the *experimental* nature of the design process as one of its core attributes [15]. Design is an experimentation that consists in reflective 'conversation' with materials of the design situation. The designer works selectively in different materials experimenting with different aspects of his design at different stages in the design process. The design representations may facilitate experimentation at low risk and cost by eliminating or inhibiting constraints of the constructed world. In this way, several alternatives can be easily created and explored. Using various design materials, the designer is able to experience how it would be in the real world.

A design approach, which emphasises, throughout the design process, the importance of experimenting with different kinds of design representations where application is simulated in a use like context, has been a particularly successful vehicle for involving users concerned with design of computer systems for work settings [10] [16]. In such cases where software is designed, software itself is a very flexible material for creating design representations in terms of prototypes; see for instance [4]. Another kind of design representation that has proved to be particularly effective in the domain of software design is 'mock-ups' which are design-models built from non-digital materials, for example, cardboard and paper [8].

An important issue in design is that of context. Since successful design requires a match between the future system and its context we need to have representations of the future context of use as well; we need to mock-up the context, so to speak. A way to address the issue of context is to work with scenarios. Scenarios differ from conventional representations like data structures and data flow in focusing on the context of use of the computer system and the interaction between these two, or, in John Caroll's words: "When we design systems and applications, we are, most essentially, designing scenarios of interaction" [6]. The definition of what constitutes a scenario has been much debated, but, as observed by Kuutti, there seems to be a general agreement that 1) a scenario describes a process or a sequence of acts, 2) a scenario refers to a situation or an episode, and 3) a scenario represents the system as seen from the users' point of view [12].

The main limitation of scenarios is, however, that they often are merely textual descriptions of a usage context. Our experience from a long history of using scenarios is that they can be just as abstract as flowchart and UML diagrams, and hence difficult for a user of a fictive computer system to relate to. Thus, even though scenarios are intended to provide contextual design, the context they provide is often difficult for a user to enter or react to.

Video-taping people is a well established and a very productive way of acquiring knowledge about work practice and use of technology as part of design processes; see for instance [2] [3] [17]. The most prevalent use of video has been for capturing current work practice and experimental use of new technology, but recently it has been suggested to use video as a way of presenting design ideas for users. Mackay, Ratzer and Janecek report on a very interesting case where video is used as a design artefact throughout a design process, including each of the phases observation, design, video brainstorming, design and evaluation [14]. Such an active use of video in design is quite different from the use of video for marketing purposes, such as " The Knowledge Navigator" from Apple [7] or like "Starfire" from SunSoft [19], which is a video from 1994 , communicating the vision of an new kind of interface expected to be available ten years later.

This paper reports on an effort to combine the elements of prototypes, mock-ups, scenarios, and conventional video in the creation of *virtual video prototypes*. The new developments offered by virtual studio technology make it possible to produce virtual computer-based mock-ups of future technology and its context by mixing physical and digital 3D objects and to combine these with the computer-based prototypes. This can be used as a stage for enacting future scenarios as scripts in a video production. In this way we film our scenario and makes it immediate and relevant to users. We argue that a virtual video prototype is a way for the designer to make the important link between a scenario, a computer prototype, and the creation of a realistic context. Hence, creating a virtual video prototype is another tool in the designer's toolbox.

The idea of virtual video prototypes is in this paper introduced in the context of design for Pervasive Health Care, which is part of Pervasive Computing. Pervasive Computing entails that interactive computing power is becoming embedded in people's everyday environment, including cars, buildings, streets, home appliances, hand-held devices, construction materials, clothes, paper, etc., [9] and www.pervasive2002.org. According to John Thackara [18], the number of microprocessors produced today for desktop computers is 2.5 percent of the total number of microprocessors manufactured; the rest are integrated parts of our physical environment. Since three-dimensionality is an inherent part of our physical world and since a virtual studio technology offers unique potential for visualising digital 3D objects and environments together with physical objects, *virtual video prototyping* seems an obvious path to pursue in order to envision future usage scenarios.

The paper progresses as follows: we start out by providing a brief overview of our current research within pervasive healthcare, which forms the context for our experiments with virtual video prototyping. The next section is a brief overview of virtual studio technology which leads to the three subsequent core sections of the article, namely the story about how the two virtual video prototypes were produced, a presentation of the actual virtual video prototypes, followed by our experiences with their use in a design workshop. The paper concludes with a short discussion.

PERVASIVE HEALTHCARE

One of the main application areas for Pervasive Computing at the Center for Pervasive Computing in Denmark is Healthcare. We have termed this research area "Pervasive Healthcare". We believe that healthcare can be significantly improved by using Pervasive Computing Technologies to create better patient treatment and to make better computer support for the work done by clinicians.

For the clinicians, we believe that Pervasive Computing Technologies can improve their use of computer systems as compared to their use today. In Denmark there has been a very low adoption of Electronic Health Records (EHR). If we look at the work of clinicians in a hospital it does not, in any way, resemble the office work that the technology behind the typical client-server EHR solutions was created for. Clinicians do not have a desk to put a desktop computer on. Clinicians seldom sit down. They move around the whole hospital several times a day. They access heterogeneous types of information all the time and in many places, in conference rooms, at the ward, at the bedside, at the coffee room, in the outpatient clinic, at home, etc. and they communicate with other clinicians all the time.

All the EHR systems developed and deployed in Danish hospitals are based on a client-server model, with large-scale centralised servers and desktop computer as clients. Our ethnographic studies of hospital work have clearly shown that this is causing problems. For example, when a nurse has to give prescribed medicine to a patient, she would need to go to the medicine cupboard, log onto to the computer by entering her username and password, find the relevant patient, find his medicine schema, find the prescribed medicine on this schema, find the real medicine, sign for pouring this medicine, log off the computer, take the medicine to the patient and give it to him, return to an available computer in, say, an office, log in by entering username and password, find the patient, find the medicine schema, find the medicine, sign that it has been given, and log off! This she has to do for fifteen patients twice a day every day. Not surprisingly, as we have observed, workarounds often are established.

In our process of designing new Pervasive Computing Technology to be used by clinicians, we developed two video-prototypes aimed at illustrating and highlighting our design ideas and the way in which this design would be realised in a working context.

The background for making video prototypes

Our main objective is to design and implement mobile and pervasive computer technologies that can be used within hospitals and address the problems of mobility and accessibility of traditional client-server based EHR's. Our research and design process is illustrated in fig. 1. Our research within pervasive healthcare is based upon obtaining a detailed understanding of the complex web of co operative activities within a hospital through ethnographic studies. At the time of writing (December 2001), a full-time ethnographer has been carrying out participatory observations of a large hospital for several months. Our design of pervasive technologies within the healthcare work-setting continually involves clinicians from the hospital in various workshops. One of our projects focuses on the medication of patients and has four themes: (i) administration of medicine, (ii) prescription of medicine, (iii) clinical conference situations, and (iv) self-administration of medicine.

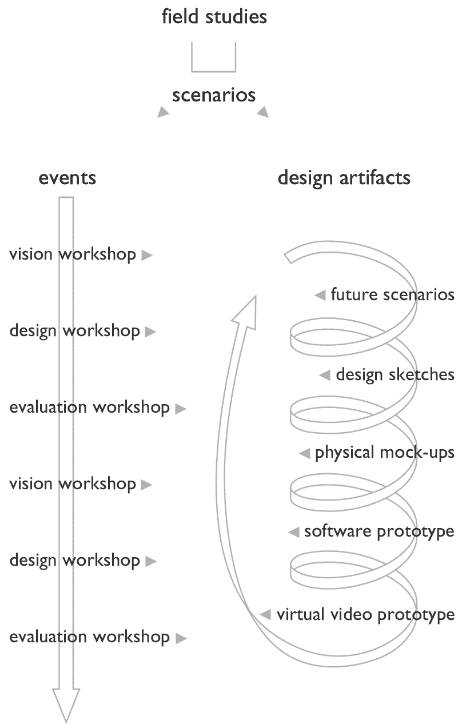

Fig. 1. Our research and design process.

Currently the second theme has been concluded, while the third is ongoing. For each of these themes we conduct three workshops in which computer scientists, doctors and nurses participate:

- *The Vision Workshop* creates visions of how to support clinical work within the specific theme.
- *The Design Workshop* tests possible solutions through scenarios, role-playing, paper and cardboard mock-ups and discussions.
- *The Evaluative Workshop* tests one or more prototypes designed and implemented between the latter two workshops.

This participatory design process uses methods like the ones described in the introduction. Vision workshops are conducted as future workshops, design workshops use all kind of cardboard and paper mock-ups and the evaluation workshop uses role-playing with a mixture of computer-based and paper-based prototypes. Scenarios are used in the role-playing and for linking things together with the ethnographic observations.

In the design workshop focusing on administration of medicine we designed four different technologies with four different usage-scenarios: (1) a bar code scenario assumed that clinicians, patients, beds, medicine-trays, etc., all had bar codes, and that nurses could document for pouring and giving of medicine by means of a bar code scanner, which was synchronised with the EHR; (2) a scenario where smartcards were used to login a user in and regenerate the state of his desktop as he left it; (3) a PDA-scenario looking at administration of medicine supported by a portable, hand-held computer, and (4) a scenario based on Radio Frequency Identity (RFID) tags that we assumed were attached to clinicians, patients and various objects, such as medicine-trays, beds and bed-tables. These RFID tags were assumed to be connected to a location tracking system, which was able to make intelligent guesses as to what was going on.

We made design sketches and mock-ups for the four technology designs and used these design artefacts in role-playing the same basic scenario: the work processes of pouring and giving medicine to a patient, and compiling the relevant documentation in the EHR. This Design Workshop raised a lot of design discussion of all kinds of aspects of computer support for clinical work. However, based on this workshop, it was agreed to pursue the RFID-tag technology, but to combine it with some features of the bar code and smartcard technologies. The mobile technology was the subject of a separate prototype.

The design was then implemented as a software prototype, which was later evaluated in the Evaluation Workshop, where the scenarios from the Design Workshop were role-played again.

While the basic idea of the RFID-tags and outline of the supporting software was accepted positively, the enactment of the scenarios at this workshop pointed towards two basic points of weakness. Because a prototype *per se* is incomplete and lacks functionality, it often attracts too much attention. For example, the RFID scanning of the presence of tags was too sensitive and constantly logged personnel in and out of the EHR, as they moved from one side to another in the same position. Hence, in prototype evaluations it is often difficult to evaluate the overall usability of the system embedded in a context. Furthermore, such hardware limitations and the lack of any ward-atmosphere made it difficult for the clinicians to adopt their roles and play through the scenarios authentically. Such limitations are common and to be expected with prototyping. However, we wanted to create a prototype environment where attention could encompass the overall contextual aspect of using a technology, while at the same time focusing on details of the particular computer-based technology to be designed and evaluated. Therefore, we decided to create two virtual video prototypes. While concrete role-playing by clinicians would not be possible in virtual video prototyping, it was hoped that other gains could be achieved by a better visualisation of what hospital work supported by pervasive computing would look like.

THE VIRTUAL STUDIO+

The virtual studio is a video technology that makes it possible to combine videos of physical objects, such as people, with video images generated in real time from digital 3D models. A method through which productions can be broadcasted directly or taped live with no further editing, at the same time allowing for real time interaction between the TV-viewer and the studio in which the filming of the physical objects is taking place. This can, for instance, be used in election broadcasts, where election results can immediately be visualised as 3D graphics, and in viewer-polls, where the results can generate elements, which are part of the digital 3D set. In spite of delays between 1 to 5 twenty-fifths of a second for calculations and synchronising, the virtual studio is said to operate in real time.

The virtual studio opens up new production methods in the professional TV-world. At the introduction of this technology, the arguments for launching it have usually been economic – produce more for less money – but apart from this cost-benefit perspective, there are other obvious kinds of opportunities, which are far more wide-reaching than simply making sports studios, game shows and election broadcasts, wherever the scenography can be quickly and cheaply replaced.

For years, TV broadcasts have utilised blue-screen technology, for example, in presenting weather reports, where the studio host stands in front of a blue or green surface that is replaced by a weather chart in the final TV-picture. The limitation of this classic blue-screen construction is that it is impossible to zoom in or move the camera. The virtual studio offers a solution to this problem in its 2D versions, and goes even further in its 3D versions, enabling work with a spatial model on the virtual set, where one can put the camera on one's shoulder or on a tripod, and move around in the virtual scenography; see fig. 2.

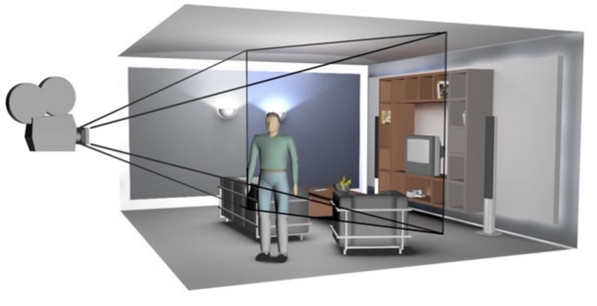

Fig. 2. Schematic diagram of a 3D virtual studio.

In principle, the technology works like this. Physical objects, including people, are filmed in a monochrome, usually blue, TV-studio. The positions of the cameras and the adjustment of focus and zoom are registered by a tracking system. This information is sent to the computer that handles the virtual scenography in the shape of a 3D model, so that it can match the virtual camera in the virtual model to the physical camera in the monochrome studio, and from this virtual camera position render a picture identical in angle, perspective and zoom to the picture, the physical camera is taking at the same time. We now have two pictures in the system: one taken by the real camera in the monochrome studio, and one generated by the computer, based on a camera position, replicating that of the real camera. These two pictures meet in the keyer, where the background colour in the picture from the monochrome TV studio is removed and replaced by the computer-generated picture; see fig. 3.

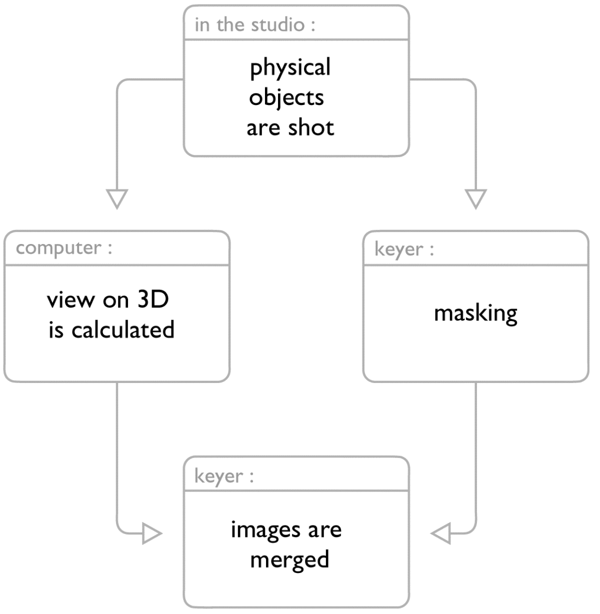

Fig. 3. Schematic diagram of the technology of the virtual studio, on a component level.

As can be seen above, a prerequisite for the virtual studio is that the physical camera in the monochrome studio is tracked for position, rotation, zoom and focus. These parameters must be registered and passed on to the computer that handles the digital 3D model, but this takes place in real time. There are various solutions for this, where the most widespread is based on a set of special surveillance camera observations of the positions of the physical video cameras in the blue studio.

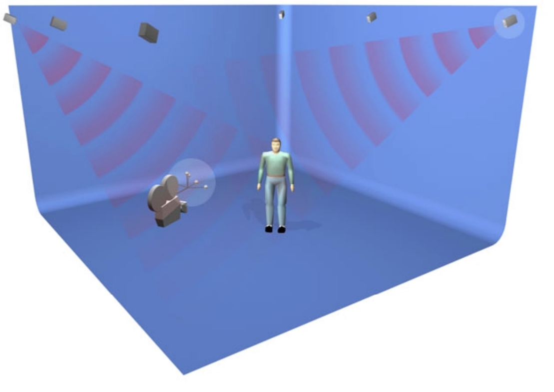

Fig. 4. Tracking.

+ This section is based on [13]

In addition, there is a metal framework with reflecting blue globes in a spatial structure on each of the physical cameras in the blue studio. These “antlers” are registered by a total of 6 infrared surveillance cameras placed on the ceiling of the studio, see fig. 4. The lenses of these surveillance cameras are surrounded by diodes that emit infrared light, and the cameras register the reflections of this infrared light in the mirroring globes on the antlers. By having at least three of these infrared cameras observe the five globes in an antler, one can, in less than a single frame, 1/25 of a second, calculate the position of the camera and send these data to the computer that produces the picture of the digital 3D model. The camera lenses’ mechanical tracking of zoom and focus delivers this information synchronously with the optical tracking.

3D modelling and animation tools

A 3D modelling and animation tool is software that allows the user to create and treat its own digital 3D models in the computer, give them texture, i.e. add visible surfaces, add lighting to the 3D models and animate them.

A modelling and animation tool has been integrated in the software used in the virtual studio in this project, which has been created and optimised for use in connection with a virtual studio. That means that this tool can be used to create models and animations that do not require much calculation (the condition necessary for real time rendering) and at the same time, a large amount of ready-to-use material is available in the form of functions and attributes not normally seen in a 3D package, but which are practical in a situation where time is essential.

The demand for simple calculation has been met by restricting the models for use in the virtual studio, such as limiting details, so that lighting calculations are not particularly involved. Furthermore, use of the built-in, ready-to-use material fosters a tendency to make products with a specific expression of TV-aesthetics, namely that of news and sports programs, the most widespread use of the technology at the moment.

However, the program can also, with certain limitations, import models and animations from more advanced 3D programs; thus more advanced features can be constructed outside the VIZ, and then imported into it. This, however, does not eliminate the limitations with regard to calculation weight.

The work process in the virtual studio

Production in the virtual studio requires some preparation. First, the production process is planned; this can take the form of a classic storyboard, giving an overview of the course of the production. In addition to the descriptions of the production process resulting from a storyboard in a conventional TV-or film production, consideration must be given to the fact that the virtual studio offers components capable of real-time interactivity. It is therefore necessary to write a description, not of what happens, but of everything that may possibly happen. A systematic review of this description will reveal all the preparations that must be carried out before the production can go on air.

First, the basic digital set must be modelled. Just as in conventional scenography construction, this will require detailed knowledge of camera movements and the action, so that the model can meet the situations which arise in the course of the production. Next, all possible interactions must be identified and pre-constructed as possible animations, available to the producer’s control. This might, for instance, be an elevation of the studio, where a quiz-contestant enters a virtual elevator on the digital set and the virtual scenography is animated to look as if the studio is sinking as the elevator continues to the next floor, where the movement stops and the studio host can leave the elevator. This type of sequence can be prepared ready for use, should it be at any time needed. If, for instance, we imagine a quiz-show where the success of the contestants determines which floor they are on, then a specific event, a contestant’s gaining a high score, will result in that person changing floors, and only in this case will the animation be ever put to use.

After all these things have been pre-constructed, the monochrome studio has to be prepared. Lighting is set, so that the light on the digital set matches the light in the physical studio, and the keyer, which distinguishes the background from the monochrome studio, has to be adjusted to function as well as possible both with regard to the lighting in question and to the people and other physical objects involved in the production. There must be cues for the participants, in the form of marks on the floor or something similar, and they must be able to see themselves on monitors in the monochrome studio. (For instance, the quiz-contestant in the elevation mentioned above should be able to see where he is to enter the elevator.) Not until all these preparations have taken place, can the production be put into on-air mode and produced, whether it is broadcast directly or taped on a video tape-recorder as a live-on-tape production.

THE MAKING OF TWO VIRTUAL VIDEO PROTOTYPES

First meeting - wishes and possibilities

As a start, the people involved were brought together to discuss the production of the virtual video prototype. A dialogue between the technique of the 3D virtual studio and the research project “Pervasive Healthcare” was started. The different points of view, including ethnographical, architectural and computer science perspectives, met together in these discussions. This resulted in the framing of the set design in relation to the user segment, such as decisions about level of detail and abstraction.

The production team agreed on the major design criterion, that it had to be a sketch production instead of a high-end production, as the prototype is seen as a tool for generating new ideas, instead of only visualising the original concept.

Furthermore, the team decided on testing the benefits of combining real and virtual objects as a way of increasing the speed of the design process. Only those objects, which did not exist or had not yet been designed, were chosen to be represented as virtual. The combination of both virtual and physical objects in the scene erased the division line and boundary between the two layers of set. Talents in an overall real-time based, virtual environment often do not seem to merge into the set, whereas a higher degree of mixing of physical and virtual realities tends to blur the overlap.

Storyboard and dialogue - idea meets the 3D-space

From the on-going discussions, a storyboard started to emerge. 3D-models, images and texts were shared to develop the scenarios. This made it possible to let all of the participants contribute to both the spatial and narrative components of the prototype. Both the space and the story were generated on each other's premises; the fact that the story had to take place in a specific set forced a clarification of unsolved matters relating to the story and its 3D-space. The combination of 3D and story telling started to evolve and concretise the scenarios and vice versa. For example, based on ethnographical studies, parts of the dialogue changed to take place in enclosed and private spaces, which previously had neither been discussed nor thought about. The intention had been to let the videoconference take place in a hallway, but it was changed to a more private location, because the spatiality of the storyboard showed the necessity to separate certain information from public areas. In this way the results of the interdisciplinary work defined new spatial constraints for the set design.

Numerous computer models were tested in the studio, clarifying tactile and physical design parameters, such as materials, textures, light settings and ergonomic improvements. As an example, it was decided to *radiosity render* (a way of calculating light in a 3D model) the light onto the textures using *Lightscape* to emphasise the atmosphere, instead of working with highly detailed geometry. Parts of the computer models were tested in relation to the physical objects in the set; virtual objects had to match physical objects and their movements were designed to avoid inter-penetration in any perspective.

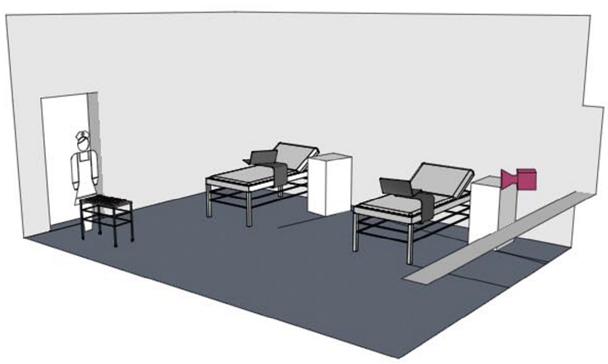

Fig. 5. Element from the storyboard.

The fact that the team worked with 3D-models in the process of storyboarding made it possible to convert the geometry directly into the virtual studio. In addition to the increased workflow, this direct link between models used in the storyboard process and the final set gave the participants involved a common idea of the spatial parts of the virtual video prototype. It turned out to be a dynamically and fast way of working, to share a spatial idea in addition to the traditional texts and images.

Recording - becoming part of the space

Working on the set with real time computer models made it possible to discuss the output on the run. The directors and people on the set could easily comment and change both the story and the set design (especially the virtual). This made it a very flexible and dynamic way of evolving the prototype.

During production the 3D facilities of the studio contributed to an on-going evaluation of lights, angles, and compositions. The composite meeting of physical objects, talents and the virtual set, examined through the perspective of the physical camera, made it possible to make last minute changes to the virtual video prototype.

Dealing with a production containing physical and virtual objects in motion required some rehearsal to avoid collision between talents and the virtual set. Because of such problems, the team had to invent technical solutions, such as allowing talents to place physical props onto the virtual set, while simulating distributed communication. Different sizes of chroma key blue boxes were placed strategically in the set, so that they matched up with virtual objects, becoming their invisible materialised surface.

Likewise, establishing two sets inside the blue studio solved some of the problems regarding the staging of the distributed communication. One camera's output was used to feed and simulate a video-conference displayed on a screen in the other set. The benefit of this setup was the enabling of a direct auditory signal between the two communicating talents, even though it looked as if they were situated in different locations.

Fig. 6. Distributed communication.

The virtual video prototype was recorded live-to-tape, and the only post-production needed was cutting and arranging the takes on a timeline. In the production phase, you are thereby always evaluating the final outputs, which is an advantage when used as an on-going and developing prototype tool.

THE TWO VIRTUAL VIDEO PROTOTYPES

The "Pervasive Hospital Bed"

This virtual video prototype illustrates how a nurse would give medicine to a patient and answer his questions in a future where the hospital is equipped with Pervasive Computing Technologies. The technologies that we wanted to illustrate in this video are:

- *Location of persons and things* – where all persons and thing are equipped with tags (RFID), enabling their location;
- *Active things* – embedded processor and communication power throughout;
- *Context-Aware Applications* – where computer applications (e.g. EHR) look up information about its current user context, such as who is using the computer, where is the computer located, who else is nearby, etc.;
- *Activity Discovery* – a technology that discovers activities in which people are engaged and provides suggestions for help with these activities.

Scene 1 – Entering an "Active Zone"

In this scene we see the nurse enter the ward and step into the "zone" of the patient as indicated by the red circles on the floor. The scene is intended to illustrate that the pervasive hospital is aware of the location of the nurse; the patient; the trolley; the bed and the computer built into the table on the bed.

Fig. 7. Entering an active zone.

In this scene the ward, the red circles and the computer on the bed are created as computer graphical objects. The red circles on the floor would clearly not be part of a real-life implementation of this location-based system. However, on the video they were added as meta-comments to the movie and hence to the design idea wished to be illustrated. However, while working with the video-prototype we quite liked the visual acknowledgement of the entrance into different "active zones" and we have decided to look further into this.

Scene 2 – The "Pervasive Hospital Bed"

This scene illustrates our "Pervasive Hospital Bed". First of all, it has an in-built display, that can be used for television as well as computer display. Furthermore, the bed is "intelligent" in the sense that it knows who uses the bed, what does he or she wants, and who is near the bed.

Fig. 8. The Pervasive Hospital Bed.

The main design challenge from an industrial design perspective was to design the combined bed-table and display in a way such that it could serve its different purposes, as a television screen, as a computer and as a table. This part of the bed was important in order to make this scenario realisable, because we needed a computer at the bed (as we shall return to in scene 4). The video-prototype forced us to make a "concrete", workable and convincing object that could fulfil these purposes and hence we produced the one shown in the picture.

Scene 3 – The "Pervasive Medicine Tray"

This scene illustrates the use of small, embedded and communicating devices. In this case, the medicine tray has computing power, communication capabilities and a display. Therefore the patient's medicine tray and the patient "find each other", enabling the medicine tray for the current patient to reveal itself, as shown in the picture.

Fig. 9. The Pervasive Medicine Tray.

In the video-prototype, the display is a computer graphical object layered on top of a real medicine tray. The video-prototype made us discuss how we would design such trays, or, to be more precise, how such trays would look like. For the prototype we settled on a large label, illustrating a large LCD display filling the whole tray.

However, in a real-world setting we would probably make it by simply using LED indicators.

Scene 4 – Context-Aware Applications

When the (right) tray is placed on the patient's table three things happen in the video. First, the table moves forward to the patient, then a red glow shows around the tray when it is placed on the table, and finally the patient's EHR is displayed on the screen, showing the medicine schema and highlighting the medicine on the tray. The table has to move forward in order to enable the patient to see anything. The red glow is, like the red circles, used as meta-communication. The latter is an example of context-awareness provided to the EHR. Because the Pervasive Computer System knows the location of the nurse, the patient and the medicine tray, it can tell the computer on the table to log the nurse in, find the patient's record, and display the medicine on the tray. In the video production, everything but the medicine tray are computer graphical objects.

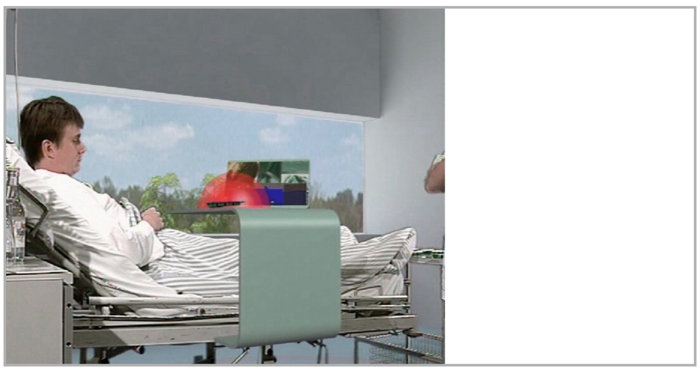

Fig. 10. Context-aware applications.

Now, to make this whole scene work, there were several thing we had to design. First of all we needed to consider how the table should work. We needed to obey the rules of nature and we needed it to look sufficiently robust and still have it moving back and forth. This clearly was a design challenge. Furthermore, we needed to consider in detail the usage scenario for this context-awareness. The video-prototype forced us to answer questions like "How can the nurse interrupt the television program he is watching?", "Is it necessary for the patient to see the screen?", "How do we ensure that it is the nurse and not the patient who logs in?", " How could a nurse and a physician use the computer display co-operatively?", and so on.

Scene 5 – Leaving the "Active Zone"

In the last scene on the video we see the nurse leaving the "active zone" of the patient. In a previous clip, we see that the nurse automatically logs off the computer and the patient's television is resumed. The design idea to be illustrated is the easy log on and off by merely approaching of the computer.

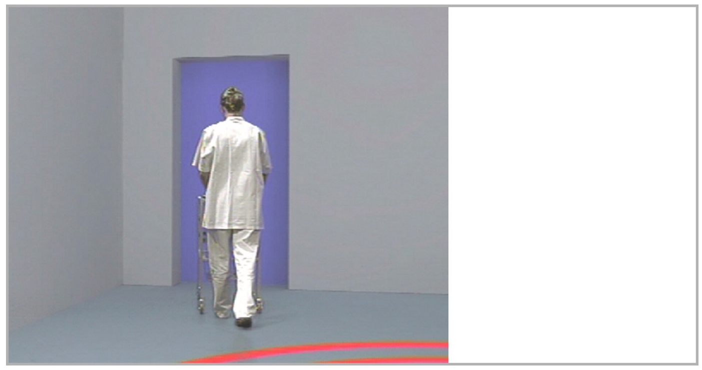

Fig. 11. Leaving the active zone.

Here the video-prototype again made us consider exactly how this automatic log on and off should work. By seeing it in context, the video raised several questions like "What happens if three persons are within the same zone?", "Can they log in as each other; can the patient?", etc.

"Mobile and Pervasive Videoconference"

The next virtual video prototype illustrates how clinicians in a pervasive hospital may communicate in the future. The story is that a physician is paged on his PDA concerning an urgent X-ray image. He receives the call and a synchronous videoconference is initiated between him and the radiologist. The physician can see the X-ray on the PDA, but the resolution is too small and he therefore walks up to an active wall display where he can log in by approaching this wall. The videoconference and the X-ray image are transferred to the wall display and the physician and the radiologist can continue their conference there. The radiologist can remotely mark the thing he is talking about on the X-ray picture to indicate what he is talking about. After the conference is over, the physician needs to leave a message for another physician, and he makes a video recording (asynchronous videoconference) and sends it of to his colleague. When he is finished, he leaves the wall and he is logged out. The technical white paper for this virtual video prototype can be found in [1].

Scene 1 – Paging a person and checking the Activity List

When the radiologist wants to page the physician, the location-service described above forwards the call to the PDA in the physician's pocket. On the PDA there is a list of so-called "Activities" that are relevant for this particular physician, and he can select the one he finds most important at the moment.

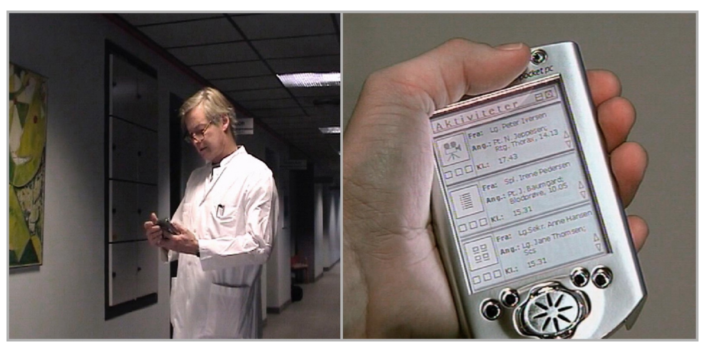

Fig. 12. Paging a person and checking the activity list.

This scene is taken "on location" in a hospital ward. In the first takes of this scene, we used a blue piece of paper for superimposing the graphical image onto the PDA later. However, this turned out not to look very convincing and therefore we changed over to creating a "real" computer-based prototype to run on the PDA's screen, and then recording this prototype. This is a good example of where the blue-screen technique does not work.

To make this scene a lot of design issues had to be settled. We needed to consider the user-interface design on the PDA in every detail, and think through the way in which the interaction would occur. Several new design ideas emerged in this process and we shall return to one of the most important ones in the next scene.

Scene 2 – Context-Awareness in Mobile Videoconference
When the physician presses the activity from the Radiology Department, he accepts the videoconference. The context-awareness described above ensures that the right context for this conference is established by displaying links to the relevant part of the patient's EHR and the X-ray picture, which is the subject of this conference. These links are displayed in the bottom of the screen and by pressing the thumbnail, the physician can call up the X-ray picture without having to find it himself.

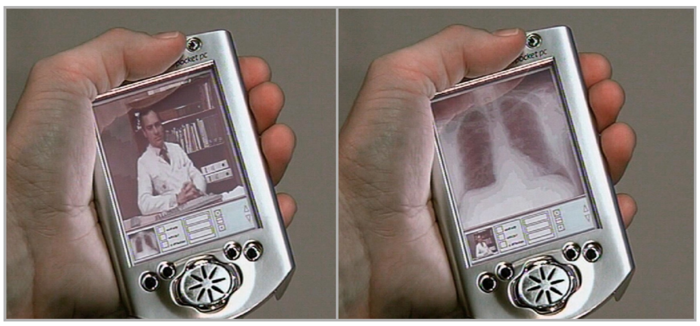

Fig. 13. Context-Awareness in mobile videoconference.

Again there is no blue-screen technique used here; the prototype is created directly on the PDA. The design idea of providing context-awareness to the videoconference emerged during the design of this prototype. We needed to design for the small screen where large overviews of patient and X-ray images are not feasible. One idea was to have the right links appear "magically", and because we already had the design of the context-awareness working for the EHR in video prototype version, we developed this design to encompass context-awareness in videoconferences.

Scene 3 – Entering an Interactive Wall
Because the X-ray image cannot be seen on the PDA the physician enters a room where there is an "Interactive Wall". By approaching the wall he can log in by pressing a button on the screen. This is similar to scene 1 in virtual video prototype 1.

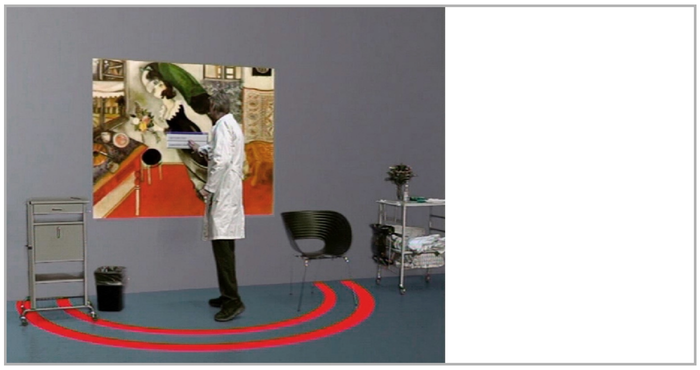

Fig. 14. Approaching an interactive wall.

When the physician enters this "conference room" he actually enters the blue studio and in this scene practically everything is created as computer graphical objects.

Scene 4 – Transferring an Ongoing Session
In this scene the ongoing session on the PDA is transferred to the Interactive Wall and the video link and the X-ray image is shown on the wall.

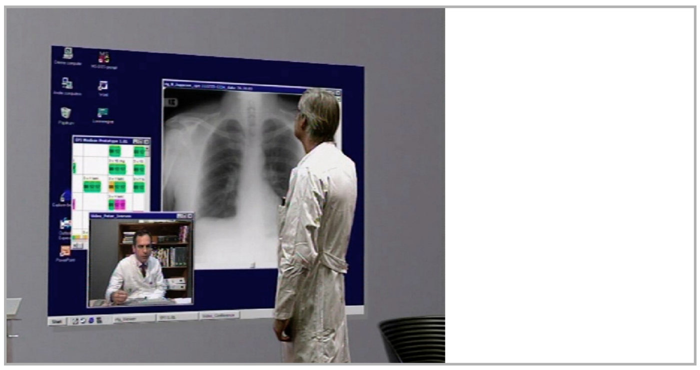

Fig.15. The session has been transferred.

This scene forced us to consider what it means to "transfer a session", a concept we have lively discussed without ever reaching an agreement. Since, however, we needed to transform "physical" situations into their virtual video prototype, we needed to consider questions like "How do you transfer sessions?", " What happens to things you are already doing, such as looking at medicine schedules?", "Does a user interface on a wall look like the one on your desktop computer?", and so on.

Scene 5 – Interacting with the Interactive Wall
In this scene the physician interacts with the Interactive Wall, finishing the conference with the radiologist, navigating some data, and sending a recorded message to a colleague.

Fig. 16. Interacting with the interactive wall.

All shown on the wall are computer made and represent our projection of our computer-based prototype onto the video recording in the studio.

EVALUATION AT A DESIGN WORKSHOP

The two virtual video prototypes were evaluated and discussed at the design workshop of the second vision-trial of the "Pervasive Health-care" project. In addition to the designers, two nurses and three medical doctors participated in the workshop.

The organisation of the design workshop was inspired by elements of the Video Card Game approach originally invented by Buur and Søndergaard, [5]. The Video Card Game is a very much further developed stage of interaction analysis principles as documented, for instance, by J. Jordan and A. Henderson [11].

The essential method of the Video Card Game is to supplement video material with physical cards, with still pictures and a blank space for annotations. We have adopted this idea with the modification that we have added to each card a fixed set of issues as a focal point for the video analysis, for example, "What works well in this scene?" and "What does not work ?". For each video we had produced in advance six or nine cards, respectively, representing the main scenes or events of the videos.

The Video Card Game approach in its original form goes through a series of slightly sophisticated steps, among which are arranging one's hand of cards and collecting card families. We have used the idea of using physical cards in a more straightforward manner involving the following steps:

1. introducing the idea and general structure of the workshop to the participants,
2. watching the virtual video prototype,
3. allowing time for each participant to make notes on his own set of copies of the cards,
4. re-running the video, stopping at the positions corresponding to each card, with time for discussion of the focus on the cards,
5. concluding discussion of the design.

Steps 2 through 5 were repeated for each of the two video-prototypes.

The issues that were raised in the cards and the ensuing discussions of the virtual video-prototype can be organised around three themes: physical space, implementation context and interaction.

Physical space

As previously argued, one of the benefits of producing a virtual video-prototype is the ability to make more precise representations of the context of which a new design will be a part. Designers are forced to think through their design in concrete detail, just as the scenarios, in which the use of a new design is played out, have to be more precise, since the aim is an "as-realistically-as-possible" video. Interestingly enough, while the hands-on interaction between the users and the future design was lost by making a video-prototype, other gains were achieved by striving for a realistic representation in the video.

When discussing *The Pervasive Hospital Bed*, for example, an immediate reaction to the virtual desktop with an in-built monitor was one of rejection. Firstly, the clinicians at the workshop objected that it would not be possible to keep up the hygienic standard if such a device was added to the hospital bed. Secondly, it was thought that the making of the bed would be too difficult. These points had not been raised in the card-box mock-up of the RFID-scenario in the design workshop of the first vision-trial, even though, or perhaps because, a card-box representing a computer-screen had to placed on top of a drawing of a patient. Probably the deficiency of the card-box mock-up required suspension to some extent of critical common sense. As a consequence of these objections, an older idea of using a TV monitor mounted on the ceiling and available to many wards in Danish hospitals was discussed. This in turn led to a discussion of privacy in the case of a hospital dormitory. Several alternatives to a monitor on the bed were discussed, including mounting the monitor on the wall or putting it on a table, which could be rolled up to the bed. This discussion forced us as designers once more to think over, whether it would be possible at all to have a monitor close to patients. Could, for example, the hygienic issues somehow be resolved?

Integrating the monitor with the wall, as suggested in the case of *The Mobile and Pervasive Videoconference*, was received as a great idea. Whereas we as designers had seen this as a tool for conference situations mainly between doctors and nurses, the clinicians at the workshop pointed to a further advantage; a large wall-monitor in the ward would be of considerable help when teaching apprentice nurses and doctors on the ward.

Finally, another major space-related issue was the size of areas sensitive to tagged objects. A prolonged discussed started out from the observation that the specific situation represented by *The Pervasive Hospital Bed* was really a special case with only one patient and a single nurse. Most wards have many beds and very often several nurses and medical doctors are present, a fact which obviously raises an important issue to consider, the size of the sensitive areas. During the day, many people enter the hospital ward to perform a variety of tasks and therefore some kind of advanced guessing on the part of the system is needed.

Context

The discussion of a significant number of use and use-context related issues was triggered by the two virtual video prototypes.

During the discussion of *The Pervasive Hospital Bed* the amount of information available from the EHR to the nurse and the patients respectively was a key issue. Especially discussed was the kind of information which would be appropriate for the patient to access. According to Danish law, each citizen has the right to access any information concerning himself or herself in the public administration, including patient records. This right to full access is, however, weakened in practice by the fact that patient records are not readily available even to patients in a hospital, since the work of doctors and nurses requires patient records to be kept in the ward offices. Furthermore, patients look into their patient record only in the company of a nurse or doctor, since clinicians fear that patients may interpret information on their health erratically. Full, real-time access by patients to their records would require, it was thought, that nurses spent more time with patients explaining the information in the records and furthermore that patients adapted to a situation where they were more informed about their situation than they actually are today. While both of these points were regarded as positive, possible developments, there was a doubt about the availability of resources, either of nurse-hours or of self-awareness in the attitude towards illness on the part of the patients.

This general discussion had a concrete parallel in the discussion of the design of the bed-table and the monitor. On the one hand, the clinicians at the workshop, especially the nurses, found information sharing between nurse, doctor and patient by the use of the same monitor to be highly positive. On the other hand, they still wanted the opportunity to access information on their own, without the patient at their side. They wanted to be able to evaluate, for example, a patient's cancer examination results before talking to the patient. When the designers pointed out, that the small table was actually designed in such a way that clinicians can access the monitor at the end of the bed on his or her own, the design was agreed to, of course, with a reservation based on the hygienic objections previously mentioned.

In discussions of *The Mobile and Pervasive Videoconference,* the doctors agreed that the provision of on-line communication with colleagues and nurses was in principle a good idea. However, the doctors objected that they already received too many notifications through the existing paging system. Therefore, notification by sound and picture via a PDA was not received positively, since doctors feared constant interruption of their work and, furthermore, they objected to any suggestion that other people should be able to hand tasks onto them without their active consent.

Interaction

As previously mentioned, doctors and nurses at the previous design workshop using card-box mock-ups were very enthusiastic about the easy way of logging in and navigating by using RFID tags. This was confirmed when discussing *The Pervasive Hospital Bed*. Furthermore, the clinicians were clearly in favour of the possibility of tracking locations of patients, medicine trays, beds and other hospital equipment, but quite reserved towards any suggestion of tracking staff, feeling it as a form of surveillance.

In connection with the medicine trays, it was discussed how much detailed information was actually needed to identify which tray belonged to which patient? On the one hand, information in terms of name and CPR number (the unique ID number for each Danish citizen) is nice to have, but all that seems necessary is some kind of lamp that blinks, indicating that is this is the right tray for the patient in question.

The idea of using video on the hand-held device was at first rejected as superfluous, since an audio signal was considered sufficient. However, it was later acknowledged that in some cases it would be relevant, for example, in conference situations, involving people from different hospitals or people who do not know each other from a day-to-day work relationship.

The monitor integrated into the wall was extensively discussed and at times conflicting arguments were voiced. On the one hand, the use of one's finger as a direct kind of manipulation for drawing the circle on an X-ray was very much appreciated, but on the other hand, it was deemed impractical to have to go up to the wall whenever one wanted to interact with the monitor. One suggestion was to have something active in the pocket to avoid having to push a button on the monitor.

CONCLUSION

This paper has presented the technique of creating *virtual video prototypes* in the virtual studio. Coming from a Participatory Design tradition, we have had years of experience in using design techniques such as computer-based prototyping, scenario-based design, paper-based design of user interfaces, cardboard and plywood mock-ups, etc. However, we often experience a need to combine these things and link them all contextually together. The design of pervasive computer technologies within healthcare was presented as our concrete case. From a methodological perspective we have suggested virtual video prototyping as a method for creating real-life virtual "mock-ups" of future technology and embodying it in its envisioned ecology.

One of the striking results of creating such a virtual video prototype is that it forces the designers to address very concrete design issues before the video can be produced. In order to create the prototype the designers cannot avoid paying attention to the physical, real-world constraints and to details in the usage-interaction between a user and the technology. There is simply no shortcut, because the director has to tell the actor or user exactly what to do and how the technology reacts in contextual usage; for example, "Do we use the finger or a pen on the screen?", "Can the table more forward?", etc. Thus, from a designer's perspective, creating a virtual video prototype makes him work with the material of design in a classical sense, thereby taking the design a step further.

For the user's perspective, we experienced during our evaluation of the virtual video prototype that it enabled users to relate to the practicalities and context of applied technology; the pros and cons of such a technology were suddenly visible in a (seemingly) real and relevant work-setting. Hence, the users can relate to the practicalities of using future technology, and practicalities are exactly what we often mean by user interface.

One of the main limitations in the creation of the virtual video prototypes described in this paper is the lack of user-involvement. The "users" in the video are actors, and there are no "hands-on experiences" from any real users. The users had provided extensive input during the workshops prior to the production, but in the actual design process while creating the video, the users were not active participants. We discussed having real users instead of actors. However, because a user does not see the user interface at the wall, for example, but is looking into a blue wall, there is little gained in having a real physician instead of an actor; the physician would not have "hands-on experience" anyway. Nevertheless, we plan to make new virtual video prototypes with real clinicians who come into the studio and role-play several alternative scenarios, which will be discussed and re-taken continuously. This is a way of extending the design-triangle of the ethnographer, computer-scientist, and the architects to encompass users as well.

ACKNOWLEDGMENTS

This research has been funded by The National Danish Center for IT Research Grant 214.

REFERENCES

1. Bardram, Jakob E. & Christensen, Henrik B.: *Middleware for Pervasive Healthcare - A White Paper*. (Aarhus Denmark 2001). Available from http://healthcare.pervasive.dk/.
2. Blomberg, J., Suchman, L. & Trigg, R. Reflections on a work-oriented design project. In Trigg, R., Anderson, S. & Dykstra-Erickson, E. (eds.): *PDC'94 Proceedings* (Chapel Hill North Carolina 1994) 99- 109.
3. Brun-Cottan, F. & Wall, P. Using video to re-present the user. *Commun. ACM* 38, 5, 61-71.
4. Budde, R. et al. (eds.) *Approaches to Prototyping*. Springer-Verlag, Berlin, 1984.
5. Buur, J. & Søndergaard, A.:Video card game: an augmented environment for user centred design discussions. *Proceedings of Designing Augmented Reality DARE 2000* (Elsinore Denmark, April 2000), ACM Press, 63-69.
6. Caroll, J. M. (ed.) *Scenario-Based Design: Envisioning Work and Technology in System Development*. John Wiley and Sons, Inc, New York, 1995.
7. Dubbcrly, H. and Mitch, D.: "The Knowledge Navigator," Apple Computer, Inc., 1987, video.
8. Ehn, P., Kyng, M. Card Board Computers: Mocking-it-up and hands-on the future, in Greenbaum J, Kyng M (eds.) *Design at Work: Cooperative Design of Computer Systems*. Lawrence Erlbaum Associates Hillsdale, NJ, 169-195, 1991.
9. Estrin, D., Govidan, R. & Heidemann, J. (guest eds.). Embedding the Internet. *Commun. ACM* 43, 5, 38-82.
10. Greenbaum, J., Kyng, M. (eds.) *Design at Work: Cooperative Design of Computer Systems*. Lawrence Erlbaum Associates Hillsdale, NJ, 1991.
11. Jordan, B. & Henderson, A. *Video Analysis: Foundation and Practice*. IRL Report No.94-0027 (Palo Alto, CA, 1994) Institute for Research and Learning.
12. Kuutti, K. Work Processes: Scenarios as a preliminary Vocabulary in Caroll, J. M. (ed.) *Scenario-Based Design: Envisioning Work and Technology in System Development*. John Wiley and Sons, Inc., New York, 1995.
13. Lervig, M. & Madsen, K.H.: Artists in the Virtual Studio. In *3D Production Methods: Behind the Scenes of Virtual Inhabited 3D Worlds* (ed. K.H. Madsen). London: Springer-Verlag, in press.
14. Mackay, W., Ratzer, A. & Janecek, P.: Video artifacts for design: bridging the gap between abstraction and detail, in *Conference proceedings on Designing interactive systems*, (New York, NY, 2000), ACM Press, 63-69.
15. Schön, D. *The Reflective Practitioner*. (New York 1983) Basic Books.
16. Schuler, D., Namioka, A. (eds.) *Participatory Design: Principles and Practices*. Lawrence Erlbaum Associates, Hillsdale, NJ, 1993.
17. Suchman, L. A. & Trigg, R. H. "Understanding Practice: Video as a Medium for Reflection and Design", in Greenbaum, J. & Kyng, M. (eds.) *Design at Work: Cooperative Design of Computer* Systems. Hillsdale, N.J.: Lawrence Erlbaum Associates, pp. 65-89, 1993.
18. Thackara, J.: The Design Challenge of Pervasive Computing, in *interactions*, (New York, NY, 2001), ACM Press, 8, 3, 46-52.
19. Tognazzini, B.: The "Starfire" Video Prototype Project: A Case History. In The Proceedings of CHI94, pp. 99-105, 1994.