Virtual Microscopy: Merging of Computer Mediated Collaboration and Intuitive Interfacing

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ABSTRACT

Ubiquitous computing (or Ambient Intelligence) is an upcoming technology that is usually associated with futuristic smart environments in which information is available anytime anywhere and with which humans can interact in a natural, multimodal way. However spectacular the corresponding scenarios may be, it is equally challenging to consider how this technology may enhance existing situations. This is illustrated by a case study from the Dutch medical field: central quality reviewing for pathology in child oncology. The main goal of the review is to assess the quality of the diagnosis based on patient material. The sharing of knowledge in social face-to-face interaction during such meeting is an important advantage. At the same time there is the disadvantage that the experts from the seven Dutch academic medical centers have to travel to the review meeting and that the required logistics to collect and bring patient material and data to the meeting is cumbersome and time-consuming. This paper focuses on how this time-consuming, non-efficient way of reviewing can be replaced by a virtual collaboration system by merging technology supporting Computer Mediated Collaboration and intuitive interfacing. This requires insight in the preferred way of communication and collaboration as well as knowledge about preferred interaction style with a virtual shared workspace.

Keywords: Computer Mediated Collaboration, Human-centered design, intuitive interface, two-handed manipulation

1. INTRODUCTION

A growing variety of consumer and professional products is being equipped with mechatronics, sensors, actuators, data storage capacity, information processing technology, communication technology and information rendering technology. Advances in network and wireless communication technology will allow us to connect such products to create smart (real and virtual) environments that can sense and reason about user behavior, intentions, emotions etc in a natural setting and react and anticipate accordingly. Users will be engaged in such smart environments in many ways, e.g. as a single user (e.g. in a hotel room, own home environment) or as a group member to a central service. Humans will be continuously connected to one another in smart environments, and information will be available anytime and everywhere[1]. There is a growing awareness that these developments will have a major impact on everyday life in near future, for example in healthcare[2], our working lives, our leisure time, and mobility. It is therefore important to take a careful look at these trends and explore how such new technologies can be geared to the needs and wishes of humans. We should focus not only on the technology but also on its consequences on human-product (in fact system/network) interaction and the changing role of humans as individuals and community members, as well on the societal values embedded in design choices that might limit user behavior, privacy and options for alternative experiences. In particular, we should focus on the human (or user) experiences evoked in such smart environments and by products with embedded intelligence as well as on how such environments and products will adapt to the sensed experiences, thus creating environments and products that support the user unobtrusively.

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This vision on smart environments was first articulated by Marc Weiser[3] of Xerox PARC in 1991. Since then, it has become known under various names including ubiquitous or pervasive computing, but the most familiar term is arguably the one introduced by Aarts and Marzano[1] at the beginning of this century: Ambient Intelligence. Nowadays, Ambient Intelligence is generally recognized as one of the major upcoming disruptive technologies. At the same time it turns out to be rather difficult to visualize the envisioned world. Usually, it is associated with futuristic smart environments, not unlike the ones presented in Steven Spielberg's 2002 movie *Minority Report*, in which information is available anytime anywhere and with which humans can interact in a natural, intuitive way, e.g. controlling a video-browsing application by means of hand gestures.

However spectacular the corresponding scenarios may be, it is equally challenging to consider how this upcoming technology may enhance existing situations. This will be the focus of the present paper. The possibility of enhancing existing situations will be illustrated by a case study from the Dutch medical field: central quality reviewing for pathology in child oncology. We will investigate how the current, time-consuming, non-efficient way of reviewing could be replaced by a virtual collaboration system by merging technology supporting Computer Mediated Collaboration and intuitive interfacing. To this end, the paper is organized as follows. First, a brief description of the state-of-the-art will be given (Section 2), followed by two studies in which the needs and wishes of the participants of such reviews have been assessed. These studies, described in Section 3, provide insight in the preferred way of communication and collaboration as well as knowledge about preferred interaction style with a virtual shared workspace. Additionally, the possibilities of multi-touch screens will be investigated in an experiment on two-handed manipulations on a touch screen as a way of introducing intuitive interfacing (Section 4). Finally, Section 5 presents a general discussion including future directions for research.

2. CENTRAL QUALITY REVIEW FOR PATHOLOGY IN CHILD ONCOLOGY

2.1 State-of-the-art

Per year, about 500 Dutch children and adolescents up to the age of 18 years are diagnosed with some form of cancer, predominantly leukemia but also other, less frequently occurring types of cancer like non-Hodgkin lymphoma or brain tumor. This relatively small group of children and adolescents is treated in seven academic medical centers, spread all over the Netherlands. In 2002, the Dutch Child Oncology Group (DCOG; in Dutch: Stichting Kinderoncologie Nederland, SKION[4]) was founded with the objective to further improve the diagnostics and treatment of this group of patients. The DCOG has its own office in The Hague from where patient material and data are exchanged with all seven medical centers. In this way, DCOG represents a virtual network organization. Within this setting, one of the main DCOG activities is carrying out referential central diagnostics. For leukemia and lymphoma the referential diagnostics is done in the central lab in The Hague. Additionally the DCOG organizes in cooperation with the haematopathologists in the medical centers regularly (i.e. half yearly) central meetings for quality control to which the pathologists and clinicians have to travel to be physically present. The sharing of knowledge in social face-to-face interaction during such meeting is an important advantage. At the same time there is the disadvantage that the experts from the seven academic medical centers have to travel to the review meeting and that the required logistics to collect and bring patient material and data to the meeting is cumbersome and time-consuming. Additionally, concerns have been raised about the way diagnostic reviews should be organized given the continuously increasing number and diversity of treatment protocols. Currently, there is a growing urgency for rapid reviewing, preferably anytime and anywhere, which is strengthened by the demands of relevant international protocols. A possible solution is to look for technology that enables such (rapid) reviewing while the reviewers stay at their own place but have the same facilities and experience as during the current (face-to-face) setting. This led to the concept of Virtual Microscopy.

2.2 Virtual Microscopy

The main objective of the central quality review meetings is to bring together the experts (pathologists and pediatric oncologists) to inspect and discuss patient material collected and organized in the weeks before under supervision of the DCOG. An example of the kind of material that is brought to such meeting is bone marrow smears on glass plates. During the meeting, the experts are looking at the patient material through a set of microscopes connected in such way that all participants view the same material at the same time (Fig. 1). One of the pathologists (the review pathologist) is leading the session by pointing out what (s)he considers important for the final diagnosis while the oncologists may supply clinical information about the patient. All participants comment and discuss the material they see through their

Fig. 1. Central quality review meeting. The photograph has been taken during the meeting in Utrecht University Medical Center on October 10, 2007.

microscope until a final conclusion has been drawn, which is written down on paper in a standardized way, the so-called Client Register Form (CRF).

Recently, several academic medical centers have started digitizing their patient material so that the pathologists may view this material on their own desktop computer. At some places, digitized patient material is already used for teaching purposes. This development towards digital (tele-) pathology yields the opportunity to replace the above-mentioned face-to-face meetings by a new system where the experts can stay at their own place during a review meeting: a virtual collaboration system based on the merging of technology supporting Computer Mediated Collaboration and Intuitive Interfacing. This requires insight in the preferred way of communication and collaboration as well as knowledge about preferred interaction style with a virtual shared workspace. The two studies investigating the experts' preferred way of collaboration are presented in Section 3.

3. HUMAN CENTERED COLLABORATIVE SYSTEMS: TWO STUDIES

3.1 Introduction

The successful replacement of the current face-to-face quality review meeting by a computer mediated collaboration (virtual microscopy) system can only be accomplished if the experts' needs and wishes have been determined and implemented. Human-centered design is a methodological approach that provides guidelines to accomplish this[5-8]. A central assumption in this approach is that the end-users, in this case the medical experts, are involved in the design process as early as possible. Basically, there are two design methods available when looking for the replacement of an existing system by a new one: empathetic design and co-design[8]. The former consists of a range of empirical research techniques that provide designers access to how users experience their material surroundings and the people in it[9,10] whereas the latter creates conditions in which users, researchers and designers can cooperate creatively, exploring ideas and concepts, e.g. through mock-ups or prototypes[11]. Empathic design methodology was employed in study 1 and the co-design approach was followed in study 2. The objectives of the pilot studies were (1) to observe how the medical meetings are currently being conducted and what the procedure is in a regular meeting for the evaluation of a patient, and (2) to assess the impact of using digital images for diagnosis in a distributed environment compared to the usage of physical samples in a normal medical meeting.

Fig. 2. Central quality review meeting. Left-hand panel denotes an impression of the co-located scenario. Right-hand panel shows one participant in the distributed collaboration scenario.

3.2 Study 1: Simulating possible scenarios

On October 10, 2007, the DCOG discipline group Haematopathology held a central quality review meeting at Utrecht University Medical Center with the following participants: five pathologists, four clinicians and the head of the DCOG central laboratory. They took part in three scenarios[12], two new ones (digital co-location, distributed collaboration) in the morning and the regular face-to-face scenario (Fig. 1) in the afternoon. The two new scenarios were organized as follows:

- *Digital co-location*: In this scenario the participants were sitting in one meeting room as in the face to face scenario but instead of having a microscope they were provided with a computer and a video beamer (Fig. 2, left-hand panel). In the computer was installed Aperio[13] Software (ImageScope slide scanner and viewer software) for manipulating a digital image. This image was the oncology sample already scanned for discussion. Only one person had the ability to manipulate the image. That image was projected onto a screen using the video beamer.
- *Distributed collaboration*: In this scenario, the participants were located in separate rooms such that two participants were present in one room looking at a digital image on a computer screen (Fig. 2, right-hand panel). Each room had (1) a conventional analog phone used to support audio (a telephone conferencing system was active) and (2) a computer with Aperio software installed (ImageScope). This software allows manipulating the digital image remotely. Anyone could manipulate the image. ImageScope not only provides viewing controls for digital slides, but also delivers capabilities not available with microscope viewing, such as annotation sharing, location referencing, and side-by-side viewing of multiple digital slides. With this software, the pathologist can effectively conduct a dynamic telepathology session, without a dedicated microscope. All the participants can see the same region of the digital slide at the same time. Standard conferencing capabilities such as leader-follower control, real-time annotation sharing, and dialog windows further enhance the digital slide sharing experience[13].

The three sessions were videotaped and afterwards the participants were interviewed and requested to fill in a questionnaire. In general, the participants preferred the face-to-face situation (eight out of ten participants) above the other situations, even though two participants preferred the distributed-collaboration scenario. Nobody found the digital co-location scenario an attractive one. According to the participants, an important reason for their preference for the face-to-face scenario was the occurrence of some technical problems that hampered the full use of the system, the most important one being the already chosen, relatively low scanning resolution of the digital images resulting in lower image quality. Moreover, the current interface of the actual software turned out not to be intuitive enough to be used as a normal tool. This observation was confirmed in the questionnaires indicating a need for clear instructions. This need to be solved in order to be able to create appropriate software for collaboration in a meaningful way. Furthermore, both observations and remarks by the participants emphasized the experienced absence of non-verbal communication because of the lack of video. This reduced the possibility for the participants to conduct the meeting in a regular way. For example, they couldn't coordinate properly the communication process and therefore needed a lot of verbal utterances to clarify the content. So, the communication was sometimes ambiguous. Despite these problems, the Computer Mediated Collaboration situation was clearly regarded by the participants as an interesting alternative for the near future. The participants indicated that they had a fair impression of the wide range of opportunities such a system may provide. For example, the distributed collaborative scenario elicited a lot of collaboration including explicitly handing over the leadership during a session (e.g., because your patient is discussed at that moment).

3.3 Study 2: Scenario-based interviews

In this study, medical experts were interviewed and asked to discuss and comment on various possible scenarios for future virtual quality reviewing. These scenarios were presented as a series of drawings[14]. The participants were instructed that the new scenarios were all technically feasible. The observations from this study are in line with those from study 1. Again, the medical experts expressed a preference for replacing the existing situation by some collaborative system where they can work together while staying in their own medical center. As main advantages they mentioned the following: (1) saving time, traveling is not needed anymore, (2) because a virtual review will take less time, more experts can be present, (3) this will lead to more interaction and discussion, (4) digital images are always and immediately available, hence there is no need to request the medical centers to send old samples when new patient material is analyzed.

In addition, the medical experts were confronted with four alternative virtual meeting situations that could replace the current central review meeting: two situations based on a central meeting room (comparable to the digital co-located situation in Study 1) and two situations with a workstation on a desk, one with multiple screens and one with a single screen. They were unanimous in their judgment: they all preferred to work behind their own workstation, a desktop computer with one screen and a camera. They considered this situation the most convenient one because the system is always available and their own documents and reports are easily accessible. At the same time, they noticed that such workplace makes sense only if the organization and logistics surrounding the review process are also changed, i.e. digitized. Next to the digital image of the patient material under discussion, the participants wanted to see the following information on their screen: a patient list, patient file (including previous reports and images), digitized (Client Registration) forms, and an overview of the persons involved in the review meeting (audio was considered indispensible, but, unlike study 1, there was less agreement about the advantages of video). They always presumed that the user interface is easy-to-use, i.e. no problem navigating through all information, and intuitive with respect to manipulating the image material (zoom-in/out, selecting, pointing, adding notes, making snap shots etc).

4. INTUITIVE INTERFACING: TWO-HANDED INTERACION ON A TOUCH SCREEN

4.1 Introduction

One of the inspiring technological features in Spielberg's movie *Minority Report* is the video-browsing application controlled by hand gestures. The upcoming technology of multi-touch enabling technology seems to be able to realize a similar kind of intuitive interfacing for manipulating images on a screen by one or two hands. This makes this new technology interesting to explore for a virtual quality reviewing system as discussed in Section 3. One- or two-handed manipulation, however, is only intuitive if the selected manipulations are perceived as fitting to the task at hand[15]. This initiated research into the user experience of two-handed manipulations on a screen[16]. Note that the research described in this section should be regarded as a first step towards developing intuitive interfaces for applications such as the quality review system.

4.2 Method

The research was carried out on a tabletop multi-touch screen: a 50 inch, 1280 by 800 pixels plasma TV screen with SmartBoard™ for Flat-Panel Displays with Actalyst Interactive Overlay using Optical Imaging technology for tracking fingers that are on the overlay surface[17]. The screen was lying horizontally on a table and the participants were standing while performing a number of tasks. Informal observations had shown that in most two-handed manipulations one hand (the non-dominant hand) was only fixating an object while the other, dominant hand was actually performing the task. We therefore selected two tasks in which this kind of manipulation was required. Furthermore, we added a third, simple task of just moving a square to compare single-handed with two-handed manipulations. The three tasks were as follows:

(1) *Move square*: a square has to be moved from one place on the screen to another. This task can be performed using one hand.

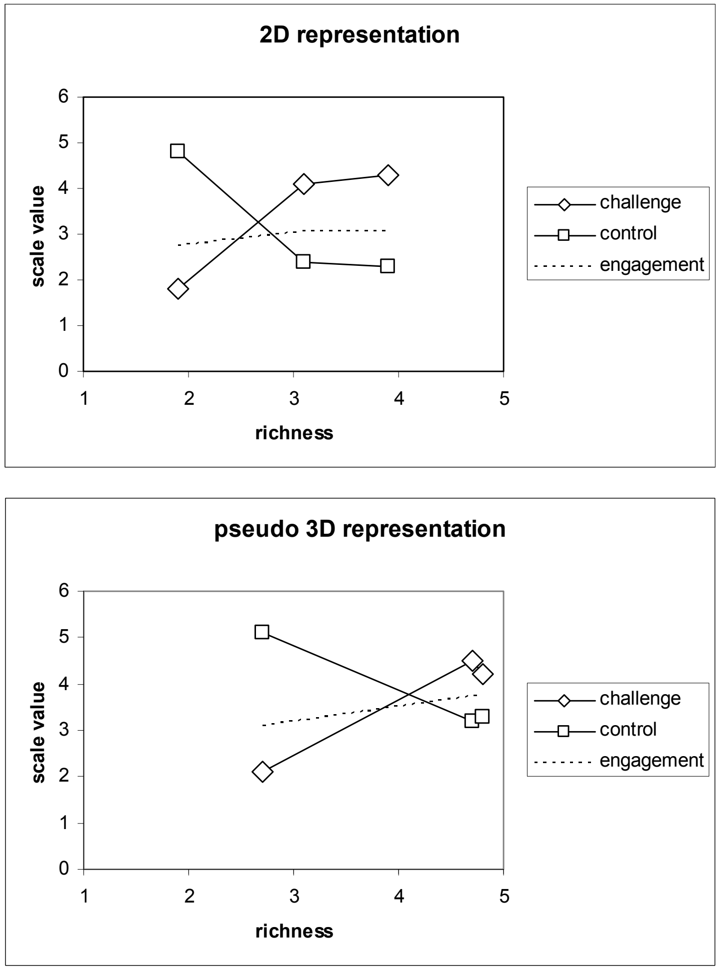

Fig. 3. Experienced sense of control and challenge as a function perceived richness.

From left to right: Task 1 (*move square*), Task 2 (*strip apart*), Task 3 (*turn disk*).

(2) *Strip apart*: a black strip (represented by three black squares in a row) is woven into a larger white square. The two objects can only be taken apart using both hands with the dominant hand on the black strip.

(3) *Turn disk*: A disk can be turned by holding an attached handle with the non-dominant hand and turning the disk with the dominant hand. The handle can also be turned while fixing the disk.

There were two representations of each stimulus. First, there was a 2D graphic (flat) version. Secondly, there was a version with a pseudo-3D representation. This was accomplished by adding features like shading and material texture. Each task was performed twice, each with one version of the stimulus. Hence, participants performed six tasks. After each task they were requested to assess the whole setting on three criteria: perceived richness of the user interface, the experienced sense of control and the challenging aspect of the setting. Richness, sense of control and challenge were rated on six-point numerical scales. In total, there were fifteen participants. Their age varied between 24 and 48, with an average of 32 years of age. They had no experience with multi-touch screens.

4.3 Results and discussion

Figure 3 denotes the perceived sense of control as well as the experienced challenge as a function of perceived richness for the 2D representation (upper panel) and the pseudo 3D representation (lower panel). The pseudo 3D versions were systematically judged to be richer than the 2D ones. In both representations, however, the simple task of moving the square with one hand was considered to be the least rich one. The task of moving the square elicited high ratings for perceived sense of control and low ratings for experienced challenge. The reverse holds for both two-handed tasks. This apparent exchange of control and challenge has already been observed in other settings[18,19] and has been incorporated in a framework integrating these percepts into experienced engagement ("…the intrinsically enjoyable readiness to put more effort into exploring and/or using a product than strictly required, thus attracting and keeping user's attention for a longer period of time…"[19]). Based on this framework, we calculated how engaging the six tasks were. The results are also indicated in Figure 3 (dashed lines). Finally, there was no effect on the judgments for challenge when going from 2D to pseudo 3D representation. In contrast, there was an effect in the ratings for sense of control in that for the two two-handed tasks the introduction of pseudo 3D increased the sense of control. Adding more details apparently made the task easier to perform.

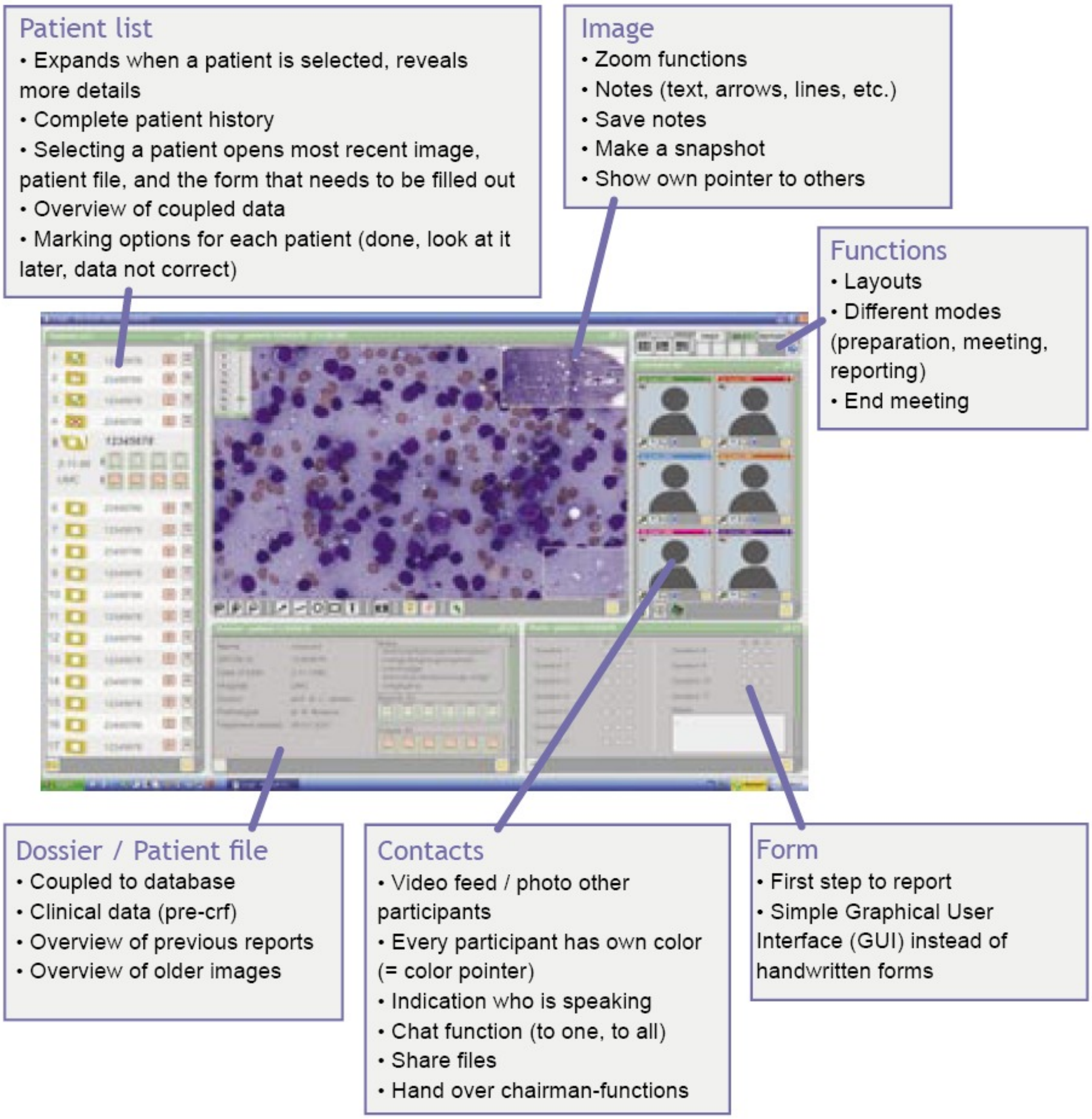

Fig. 4. Proposal for a new user interface for central quality reviewing. Picture taken from Tijsma[14].

5. GENERAL DISCUSSION AND CONCLUSIONS

The main objective of this paper was to investigate whether an existing situation can be enhanced by introducing (features of) smart environments, in particular features from Computer Mediated Collaboration and Intuitive Interfacing. As a case study, we took a situation from the Dutch medical field: central quality reviewing for pathology in child oncology. Following a human-centered design approach, the medical specialists were involved in producing ideas for a future virtual review meeting system. In general, they were positive with respect to replacing the current face-to-face meetings by a virtual meeting system. In particular, they expressed a preference for replacing the existing situation by some collaborative system where they can work together while staying in their own medical center behind their own desktop computer. They considered this situation the most convenient one because the system is always available and their own documents and reports are easily accessible. At the same time, they noticed that such workplace makes sense only if the organization and logistics surrounding the review process are also changed, i.e. digitized, and the user interface is easy-to-use, i.e. no problem navigating through all information, and intuitive with respect to manipulating the image material (zoom-in/out, selecting, pointing, adding notes, making snap shots etc). Hence, for future research it is crucial to focus on the user interface. Figure 4 summarizes a first proposal for a new type of interface incorporating the suggestions and ideas from the medical experts. Next to the interface, much attention has to be paid to the logistics. For example, information of the patient has to be available on the screen implying that the interface should be linked to a data base with patient information taking privacy issues into account. Currently, all participants have to fill in all kinds of forms during the review meeting resulting in much redundancy. This can be solved by sharing digital forms. Another topic of research will be the teleconferencing system required. Excellent audio is definitely recommended, because the experts in general prefer a situation where everybody can speak whenever needed. The possible benefits of using video on this kind of virtual meetings has still to be established. Finally, research should be done on the preferred kind of intuitive interface. Our study on two-handed manipulation on a multi-touch screen suggests that this new technology might be an interesting way of manipulating patient material represented in digital images.

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