Organising multimedia technology for real-time transmission of image-guided surgery

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ABSTRACT

With multimedia technology in medicine, new opportunities and challenges emerge, as does problems that need to be solved. Some of the issues that arise when multimedia technology is introduced into surgery are explored, with a focus on the local context of an operation theatre. Based on empirical studies of real-time, interactive transmission of high-quality video and audio, the paper considers some of the technical, medical, and organisational challenges and possibilities.

1. INTRODUCTION

Multimedia technology and networks are increasingly being utilised within medicine. One of the most fruitful areas for deployment of this technology may be the field of image-guided therapies. In image-guided surgery the medical image is the surgeon’s central source of information, and is easily available for capture and transmission. However, the central role of the image necessitates high-quality audio and video streams. Real-time conferences with a sufficiently high quality level require high bandwidth networks. This paper reports from an experimental development project utilising high bandwidth networks with high quality audio and video. The potentials and challenges were identified, and guidelines for how to utilise this technology in patient treatment were worked out.

2. RESEARCH PROGRAM

During the last two years the Interventional Centre at the National Hospital and Ullevål Hospital (The two largest hospitals in Norway) have carried out a telemedical research program. The DIMedS project (Development of Interactive Medical Services) focused on distant learning in radiology and surgery. The partners in the project was Ullevål Hospital, Telia, Ericsson, the University of Oslo, and the Interventional Centre (Buanes et al., 1999, Hanseth et al, 1999, Røtnes et al, 1998). This project utilised an ATM network (Asynchronous Transfer Mode) at 34 Mbit/s, which is a so-called “broadband”, or high capacity transmission technology. In addition to telemedicine via the DIMedS link, ordinary ISDN videoconferencing and satellite transmissions were employed.

3. RESULTS

3.1 Organisation of equipment

The local network at the Interventional Centre (Fosse et al., 1999) is described here as an example of organisation of equipment for real-time, high quality telemedicine. The Centre has an internal audio and video network connecting
two operation theatres, (one is equipped for combined radiological and surgical procedures, and one is an open MR room), two lecture halls, and a mixing and control room. One of the operation theatres is equipped (for multimedia) as follows: Two remote-controlled video cameras are mounted in the operation theatre (on the wall and in the roof). These cameras were permanently connected to the network, and the camera movement and zoom was controlled from the control/mixing room. To avoid surveillance problems the camera system had to be turned on within the operation theatre, and a red light “on air” lamp was lighted when the image signals from the cameras were transmitted.

A large challenge is to provide a “rich” environment and include enough information to mediate the important information. Several video signals from the different pieces of imaging equipment may be transmitted (laparoscopic image, x-ray image, anaesthesia monitor screen etc, a total of eight video signals). In image guided procedures like laparoscopy, the laparoscopic camera is of course the most central image source. Often other images (e.g. ultrasound image, second image from a so-called “mother-and-child-scope” or a gastroscope in addition to a laparoscope) is used in the procedures. These images can be transmitted either separately or in a Picture-in-Picture-manner (PIP) within the e.g. the laparoscopic image, i.e. as one single image instead of two separate images. Ordinary analog x-ray images were used in several procedures, but a permanent set-up for capture of these was not present. An ordinary video camera (movable) was used for this, and also for capturing other aspects (operation room nurses’ and radiographers’ work).

The room is also equipped with roof-mounted loudspeakers and microphones. The sound signals were transmitted to the loudspeaker and from the microphones on permanent XKR cables.

The presence of several image sources necessitated a mixing facility. This was provided in the control room where 16 small monitors provided a black-and-white image of all the images from the two operation theatres. Video and audio selectors provide opportunities to select and display the desired visual information on a large screen and the audio through loudspeakers. Additional connections are also possible through the control room, both to two local lecture halls and to external networks (ISDN, ATM, or satellite).

The presence and use of several image sources led to a problem that emerged during some procedures. The surgeon’s primary image source may change rapidly and frequently (e.g. between laparoscopic video, 3D reconstructed CT/MR scans, x-ray cine, ultrasound etc.). It is possible for students or visiting surgeons to follow this rapid change of focus when they are present in the room and can watch the surgeon working. However, when only one image source is transmitted to the receivers, they may not be aware of this shifting. Only the technicians (in the control room) watch all the images, and since they do not know the procedures, it may be problematic for them to decide which image to transmit.

Some possible solutions to this dilemma may be to:
• Transmit several image sources in parallel and let the receivers decide themselves which one(s) to display on the main monitor.
• Educate the technical support personnel, so that they understand more of the medical content of the transmission.
• The image use may be explicitly commented by the surgeon or by e.g. a student’s facilitator present in the room. By analogy to TV or movie production, this corresponds to the role of a “medical producer”.

3.2 Organising the use of the technology
This transmission facility was a necessary, but not sufficient element in order to obtain and transmit the different images. Support technicians and operation room nurses had to perform additional work: turn on camera system and connect equipment beforehand, adjust microphone position when the sound quality was sub-optimal, and move equipment that stood in the way of the camera view etc. Surgeons had to speak into the microphones for communication with the receivers. Patient consent was asked before the transmissions started, and patient identifications on e.g. x-ray images were blanked.

Interactivity was not hampered by a slight, but noticeable delay of audio and video. Sound was reproduced through loudspeakers, and when using room microphones (which were not “push-to-talk”), the sent audio was captured and transmitted back as echo. This is a disturbing feature, and echo-cancelling techniques should be employed in equipment. Room microphones may in some setting be preferred over individual microphones (e.g. in discussions and meetings where several people are talking it is cumbersome to pass around single microphones or controlling sound mixing). In some cases “push-to-talk” microphones are found to be best, for example when some activity occurs “in parallel” that should not disturb the procedure as such, like when the receivers discuss the procedure among themselves.

The operation theatre team was provided with the outgoing image (the resulting image after mixing) that the receivers would see. This kind of visual feedback provides the participants with a means for control over this new communication situation. They would then know which camera was used, if the camera zoomed in on a detail etc. On other occasions the image of the receivers at the other end was also displayed inside the operation theatre, and the team could then see if anyone (and whom) were present and were watching them.

We found that the task of coordination is important and non-trivial. Coordination is more complicated with real-time transmissions than it is with asynchronous (“off-line”) use of multimedia technology. A scheduled transmission may require effort to fit a suitable patient into the operation programme, reserve the equipment and network resources, and the senders and receivers may have to negotiate other pre-planned work tasks. Coordination is also necessary within the technical team. The technicians have to arrange a time for establishing the connection (which required simultaneous work at both sites), discuss the procedure with the surgeon in order to plan the
equipment set-up, or perform audio testing between sites (which in its nature is very interactive).

3.3 Image compression
Digitising video generates enormous amounts of data, and lossy (irreversible) compression is necessary. This implies loss of information from the image. Most of the lost information is redundant and insignificant, but the compression may also introduce artefacts and visible degradation of the video. This is a necessary compromise between quality and transmission or storage capacity. The large demands to image quality in tele-consultation in image-guided therapies dictated the choice of technology in this project, and real-time video and audio compressed to 8 Mbit/s using the MPEG2 standard was evaluated by expert surgeons to be fully acceptable. The time delays, reliability and stability of the ATM network were also found to be satisfactory.

4. DISCUSSION
Wide bandwidth networks is the best choice for transmission of audio and video for image guided therapies. These provides sufficient image quality (and Quality of Service in general).

Our position is that an analog video-technology network is still an adequate choice for image capture and mixing locally. The present price level, availability and complexity of digital image technology are the main reasons for our choice. Analog video-signals can be transmitted over short distances, and can be stored on videotapes. However, digital video is required if one wants to exploit the new possibilities for storage and distribution, and our choice is to digitise the video “between” mixing and transmission, before the video (and audio) leaves the department.

Utilising multimedia technology in patient treatment introduces a new medium for communication in health care. This is not trivial, as the medium has both limitations and possibilities. And implies organisational consequences in terms of cross-disciplinary work and the need of “professional” production assistance.

6. REFERENCES

Fosse, E., Lærum, F., Røtnes, J.S.
The Interventional centre – 31 months experience with a department merging surgical and image guided intervention. Minimal Invasive Therapy & Allied Technol, December 1999
