Utilizing Multimedia Technologies for Interactive Telesonography

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ABSTRACT

This article deals with telemedicine and in particular with telesonography. Telesonography is real-time video collaboration for remote ultrasound examinations. We present here an interactive videoconferencing system that supports the various fields of ultrasound expertise, utilizing multimedia technologies. The work here focuses on integrating such a system in the demanding environment of ultrasound examinations, including integration of multimedia tools and support for a graphical user interface.

We introduce an original logical model for telesonography and detail its architecture. Special emphasis is given to describing the multimedia technologies utilized in the architecture layers. This design was implemented in the TeleUS prototype, tested in a series of simulations and experiments, and proved adequate. We elaborate on this work and the conclusions reached, throughout the article.

Keywords

Telemedicine, teleradiology, telesonography, ultrasound, multimedia, videoconferencing, user interface, software tools

INTRODUCTION

Teleradiology belongs to the field of telemedicine. Telemedicine deals, in general, with remote medicine, i.e., with medical applications based on communication services. Teleradiology focuses on digital storage and transmission of medical images and films, also called PACS (Picture Archiving and Communication Systems). Real-time ultrasound transmission systems are called telesonography systems [10].

The importance of teleradiology lies in the improvement of medical service and in the availability of quality medicine, mostly in distant areas. The ability to consult and receive remote expert opinion provides an opportunity for faster and improved medical services. Also there are major financial advantages here for distributed organizations (e.g., use of a central diagnostic center) [7].

One of the more important areas of teleradiology is telesonography [4, 5, 8]. The frequent use of ultrasound for obstetric medicine and the growing experience in using ultrasound technology for a variety of other examinations turned ultrasound into a very important diagnostic tool [1]. This created the need for expertise collaboration beyond location confines. Thus, the high motivation to implement telesonography. However, telesonography is a very demanding field because it requires a high data transfer rate for direct involvement of experts in real-time.

Moreover, ultrasound is used in various fields of expertise: radiology, obstetrics and gynecology, and cardiology. The characterization of the examination changes from field to field, as are the requirements from the telesonography system. While internal or gynecologic examinations require still images for diagnosis, obstetric and cardiologic examinations require video sequences. On the other hand, physician involvement in gynecologic or cardiologic examinations is low, while it is high in obstetric and internal examinations. In any case, in all examinations, an additional expert opinion is often sought after.

Teleradiology, in general, and telesonography specifically, are based on the use of communication media to transfer medical information [4]. The standard used for teleradiology communication is defined by ACR/NEMA DICOM (Digital Imaging and Communication in Medicine) [2]. Among the various communication technologies used in the field: Plain Old Telephone Service (POTS), Integrated Services Digital Network (ISDN) and optic-fiber lines with high bandwidth (ATM, Frame Relay) [12].

Teleradiology integrates diverse kinds of media for Human-Computer Interaction (HCI) through communication networks. These are the same characteristics of multimedia (MM) technologies [6]. Specifically, telesonography systems can use various Video Conferencing (VC) tools and applications [3]. VC enables the users to take advantage of a variety of tools: audio, video, whiteboard, chat, etc. Moreover, VC can support group work [11] to enhance the usability of telesonography.

The contribution of this article is in the deployment of standard MM/VC technologies for the special requirements of interactive telesonography. The emphasis here is mainly on the design of a generalized architecture and adequate user interface for a telesonography system that supports the interactive needs of ultrasound personnel and the patients requiring their care.

The article is structured as follows. The next section presents the proposed logical model for interactive telesonography. The section following details an open multi-layered architecture with emphasis on multimedia technologies and tools. The last sections describe the implementation and experimentation done. A concluding discussion ends the article.

A LOGICAL MODEL FOR TELESONOGRAPHY

Since a model that defines the process and modes of telesonography has not been fully presented, we developed a logical model for telesonography [10]. This model characterizes the various requirements to be supported in a telesonography system, and defines the different work modes and needed connections for telesonography.

Assumptions

In order to succeed with telesonography, one has to take into consideration many factors: human, environmental, technical, and economical. The obstacles are many too - ones related to distant diagnosis, others to economical factors in building a cost-benefit model, and also general technical considerations [7]. Some of the most important and relevant aspects of telesonography are:

1) Physician involvement is essential while the patient is still on the examination table [4]. Since most ultrasound diagnostics require extensive information regarding the overall state of the patient, this leads to cooperative work of the sonographer and physician.

2) Physician time is an expensive resource. Therefore, a sonographer usually starts the examination alone, with the physician usually being involved only at a later stage.

3) There is interference to the traditional relationship between the patient and the physician [9]. Lack of personal touch can distress the patient and disturb the physician in the diagnosis. Hence, the physician and patient need enhanced personal interaction [4], i.e., both audio and visual contact during the examination.

4) Audio interaction is important because most consultation is through speaking [13]. Thus, the audio connection must be of high quality.

5) Access to previous examinations is needed [4]. Hence, the full patient file should be sent to the physician or viewed interactively.

6) Visual information is a shared resource - synchronized viewing of it is needed [13]. Therefore, a telesonography system should provide means to share visual information through collaboration.

7) Brainstorming is very popular and beneficial in the medical area. Hence, telesonography should fully support group work capabilities [3].

Terminology

Before describing the various model connections and work modes, one needs to establish a unified terminology, as follows.

The three main participants in an ultrasound examination are the patient, sonographer and physician (see left triangle in figure 1). In telesonography, the sonographer is not always present. This is so because the physician has to do some of the examinations anyway.

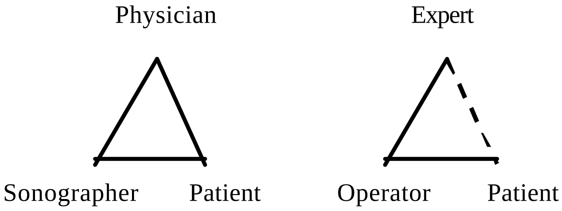


Figure 1: Participants relationship triangle

In order to avoid repeating throughout the phrase “physician or sonographer”, we refer to the person holding the ultrasound probe during the examination as “the operator” who operates the ultrasound device. The physician, when remote, is referred to as “the expert” that provides the expert consultation. This corresponding relationship is diagramed in the right triangle of figure 1.

Connections

When working remotely, several connections exist among the participants. Our model defines five connections:

1) **Voice connection** – audio for talking and hearing.

2) **Visual connection** – video for viewing all or certain participants.

3) **Ultrasound connection** – for real-rime ultrasound video transmission.

4) **Information connection** – for transferring data among the participants.

5) **Coordination connection** – for signaling and synchronization of the involved sides.

The model defines the work modes based on the above connections.

Work Modes

For telesonography, several work modes need to be supported using various connections. The model relates to them in stages, as follows:

1) **Local work –** the first stage, in which the operator does the ultrasound examination stand-alone.

2) **Remote work** – interactive work of the operator with the expert. This remote work has a few sub-modes:

   a. **Remote background work** – a telesonography examination in which the operator and the expert are communicating, but the patient's file, images and video clips are transferred between them in the background. This mode is divided into two sub-modes according to the type of patient file transfer:

      I. **Transparent transfer** – when the file is transferred without interaction between participants, or even in batch.

      II. **Interactive transfer** – when the participants talk and interact while the file is transferred.

   b. **Remote scaled work** – a telesonography examination in which the expert views the operator's display in lower quality, while full quality information is transferred as in remote background work.

   c. **Remote full work** – a telesonography examination in which the expert views the operator's display in quality close to the original, thus enabling a direct diagnosis of the examination.

3) **Group work** – a group of distant experts is in mutual contact with the operator for consultation of "conference talk" sort [3]. This work mode can use all the above remote work sub-modes.

MM/HCI Considerations

Various MM/HCI considerations arise in the use of interactive telesonography. The following discussion exemplifies some of these considerations.

When using telesonography, the contact between the expert and the patient is weak (therefore shown as dashed in the right triangle of figure 1). Clearly, there is a need to strengthen this connection. There are two alternatives for this:

1) **Indirect interaction** – the operator acts as a mediator between the expert and the patient.

2) **Direct interaction** – the voice connection is used also for interaction between the expert and the patient.

With indirect interaction, the patient cannot disrupt the discussion between the operator and the expert. However, this non-direct communication between expert and patient might cause the patient to feel left out, leading to discomfort. With direct interaction, the situation is reversed – the patient feels more comfortable but could disrupt the consultation. Note also that direct interaction is technically more complex because there is a need to manage two audio inputs, for both the operator and patient, on the same computer.

The telesonography staff should select the preferred alternative based on MM/HCI considerations, such as examinee (e.g., adult, child), technical constraints, etc. Similarly, the physician-patient interaction could be enhanced using visual/video connection to allow the physician to view the patient and vice versa.

Regarding the ultrasound connection, it is highly important for the expert to view the ultrasound video in order to get the whole picture regarding the patient. For example, being able to examine the nearby organs to determine the overall state of the patient. In addition, this connection also enables the expert to direct the operator to show the needed views.

After introducing the model, and before describing the implementation, the architecture is now presented.

OPEN MULTI-LAYERED ARCHITECTURE

To support the logical model, an open multi-layered architecture has been defined [10]. The architecture, shown in figure 2, defines a communication infrastructure at the bottom layer, above it is a hardware layer, above it a tool layer, and the upper layer is the user interface layer. Note that for the tool layer, its components are displayed.

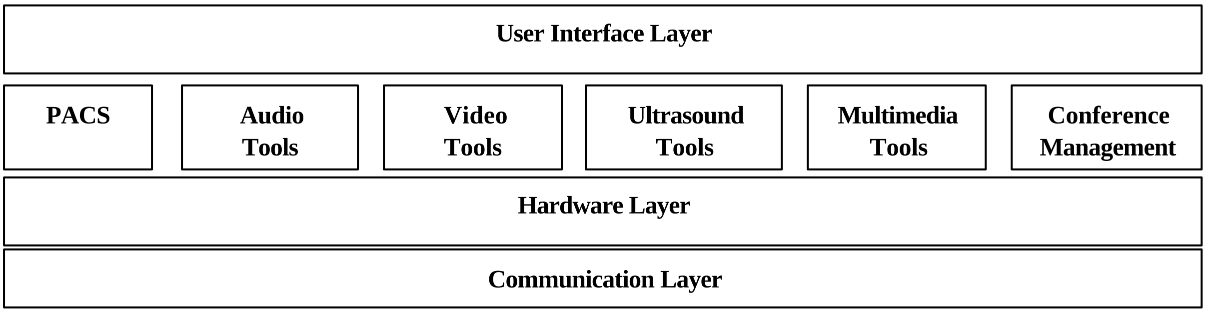


Figure 2: Architecture with the tool layer expanded

In a bottom-up description of the architecture, the communication layer supports the communication infrastructure that supplies the communication channels [12]. Thus, the communication layer defines the bandwidth limits and constrains the application to certain work modes.

The hardware layer provides the VC system type: private, roll-about, or a meeting room system [3]. It supports convenient work through appropriate displays and cameras, audio devices (e.g., cordless headset) and other hardware devices available to the users.

The next layer is the tool layer whose components are depicted in figure 2. The tool layer provides support for PACS, and for the audio, video and ultrasound tools. Also, it provides needed multimedia tools and conference management for telesonography. The PACS should be integrated into the ultrasound device itself or attached to the telesonography system, in order to provide a computerized patient file and enable retrieval of previous examinations. The audio tools must be of good quality, since the voice contact between the operator and the expert is vital. The video tools can be useful for the participants, since they can give the patient the feeling that the expert is closely involved in the examination, and give the expert a point of view on the examination room and the patient. These tools can be implemented using any existing video codec, as long as it is suitable to its viewers.

Another component of the tool layer is the ultrasound tools. These tools are vital since they enable the expert to be involved in the examination itself and see the information in real-time. Ultrasound consists of very sensitive information that passes through the communication lines - therefore it is important to select a suitable VC codec for it. Such a codec should provide a high quality as possible and be adaptive to the communication network used. The DICOM standard did not relate to codecs specifically, but since it related to JPEG, standard codecs based on JPEG (i.e., DCT), such as H.261 or M-JPEG, can be considered for use. One of the major problems of these codecs is their limitation to CIF image size, rather than PAL, thus reducing the resolution to about a fourth of the origin. And in addition, they produce blocking artifacts. However, new kinds of codecs can be built and used, but first need to be further investigated. For example, a Wavelet based codec can have a high compression ratio without producing blocking artifacts. Still, Wavelets tend to blur sharp edges in high compression ratios.

An important component of the tool layer is conference management. This tool should provide channel manipulation and control, priority assignment, synchronization and group communication management. It is responsible for participants' coordination, such as admission control, handling of channels, compression methods, etc.

The upper layer of the architecture is the user interface layer. A user interface should provide all the required services to the participants. It should be comfortable and easy to use, while enabling maximal control of the remote expert over the operator's devices. Thus, enabling the operator to perform the ultrasound examination with minimal disturbance. Further design guidelines for the user interface are detailed in the next section on implementation.

There is interaction between the above layers (see figure 3). The user interface layer, in terms of the model, deals with connections: information, voice, visual, ultrasound and coordination. These connections utilize tools in the tool layer, which activate hardware devices in the hardware layer, which manipulate the channels of the communication layer.

The information connection uses the PACS and MM tools in the tool layer. It can deploy special hardware devices such as an electronic board, for transmitting data, using the data channel in the communication layer.

The voice connection uses audio tools such as audio codecs in the tool layer and hardware devices such as microphones and speakers. The data of this connection is transmitted through the audio channel.

The visual and ultrasound connections are similar in their use of VC video tools, but they vary in the types of VC codecs used and in the hardware devices. The visual connection uses standard codecs while the ultrasound connection can use specially tailored codecs. The hardware devices used for video are cameras, and for ultrasound, it is the ultrasound device. Transmission is done using the video and the ultrasound channel, respectively.

The coordination connection uses VC management tools, such as channel distribution, etc. It exploits special hardware devices such as control board, remote control, etc. Its control data is transmitted using a signaling channel.

Model/User Interface Layer	Tool layer	Hardware Layer	Communication Layer
Connections	Tools	Devices	Channels
Information connection	PACS, MM tools	Electronic board	Data channel
Voice connection	Audio codecs	Audio devices: microphones, speakers	Audio channel
Visual connection	Video codecs	Cameras, displays, etc.	Video channel
Ultrasound connection	Video codecs	Ultrasound device	Ultrasound channel
Coordination connection	VC conference management tools	Control devices: remote control, control board	Signaling channel

Figure 3: Interaction between architecture layers

After defining the architecture, there is a need to examine both the model and the architecture to check for their applicability. For that purpose, three common cases were presented [10]: a large hospital, a medium hospital, and a remote small clinic. For these three cases, architecture packages, containing different components of the layers, and correlating to the logical model, were configured and presented. These packages, covering the different requirements, showed that the architecture is flexible and suitable for telesonography.

IMPLEMENTATION

Now the road has been paved for simulations and experiments. For that purpose, a prototype was developed [10]. The prototype was called TeleUS for double meaning: it supports Tele-UltraSound and because it sounds “Telecommunicate us”.

The computerized environment for the prototype was desktop PC/Windows and standard shareware/freeware software. The advantages of this selection were three:

1) Availability – the physicians can use their PC at home or in the office.

2) Cost – standard software costs less, especially freeware.

3) Assimilation – easier learning and maintenance for the medical and technical staff.

The following software packages and tools were used:

1) MS Windows 95/98/NT, as operating systems. They provided dialup service used for the IP connection. Windows NT was used as the host for the dialup service.

2) MS Visual C++, used as a general development tool, and also for GUI (Graphic User Interface) development.

3) MS NetMeeting (NM) v2.1, a freeware, as a VC Tool. It provides both a standard user interface and a Software Development Kit (SDK). The SDK supplied:

- Audio codecs: G.711 and G.723.
- Video codecs: H.261 and H.263. Additional codecs (user defined) can be installed as well.
- Audio channels – one only in each direction.
- Video channels – one only in each direction. Consequently, the video and ultrasound streams, from the operator to the expert, cannot be both transmitted at the same time.
- Data channel and FTP channel, both allowing data transfer, though the data channel is more efficient.
- MM tools: whiteboard and chat.
- Conference management, using H.245, enabling also group communication.
- Intel Connection Advisor, for visualizing A/V channel statistics (see figure 8).

4) WinRAR, shareware software, for lossless compression of images.

5) Winnov capture card and its SDK. Winnov is a multi-user video card that enables image capture in PAL resolution. Winnov SDK enables capturing and saving of images and video clips, in the formats: BMP, JPEG, and AVI. Note that the use of this specific card in TeleUS is optional.

TeleUS was designed for internal ultrasound. It supports **local work** and **remote work** of both **background** and **scaled**, and utilizes a variety of multimedia tools. TeleUS also includes monitoring options for evaluation purposes [10]. The monitoring utility displays system messages and records measurements in a log file (reviewed in the experimentation section).

TeleUS was divided into two programs, each with a different functionality: Operator (TeleUS-Operator) and Expert (TeleUS-Expert). These two programs are designed to work together from the different locations.

User Interface

The physician may be acting both roles: as an operator asking for a second opinion from an expert, and as an expert diagnosing from afar. Hence, the two interfaces were designed with the same “look and feel” and support common features. TeleUS is presented here in three parts: common features, operator interface (figure 4), and expert interface (figure 5).

The application’s window is centered in the background with action bars mostly at the top and log messages at the bottom. The separate ultrasound window is always on top because it is the most important part of the application, and since it is a smaller window it tends to hide behind the interface background.

Both TeleUS interfaces support the basic actions: calling, talking and hearing, sending and receiving video, control over the audio volume, cleaning the current examination area, and activation of chat and whiteboard.

In order to streamline the process, a predefined list of experts, from which the operator selects the expert, can be prepared. Once one of the sides calls, the call is answered automatically by the application of the other side, and a session is initiated. The audio levels are usually set at the start, by adjusting the speakers and microphone level bars.

Pressing ‘Clear’, cleans the examination work area while transferring the control, images and clips files to a different location for long-term saving. The two interfaces enable activation of chat and whiteboard (see figure 6), using a single button, which activates the tool automatically also on the other interface. In both interfaces, when a certain action is not possible, its button is disabled, to prevent mistaken activation and user confusion.

Operator Interface

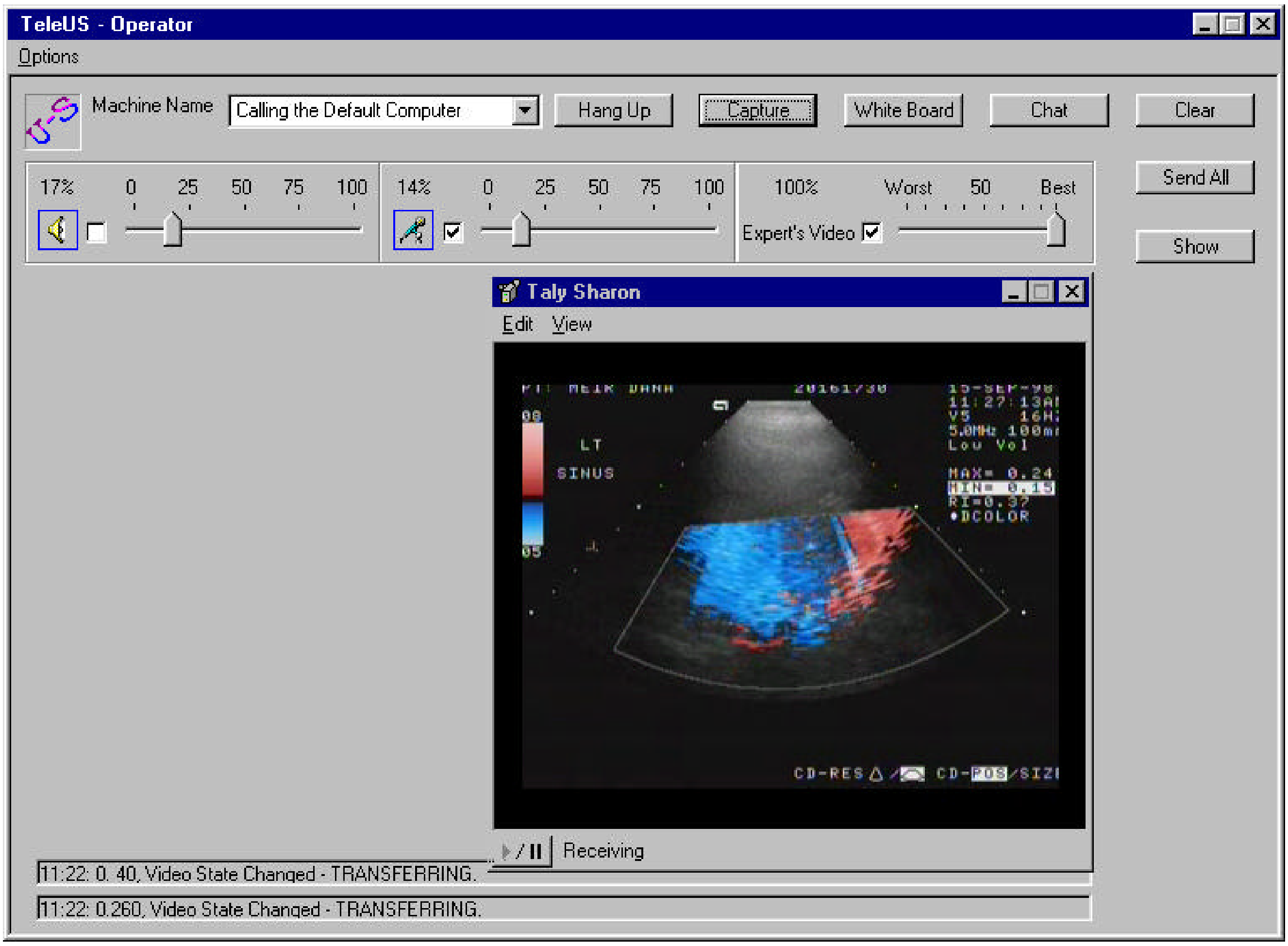
The TeleUS-Operator interface, presented in figure 4, was designed to be highly simple because the operator is busy operating the ultrasound device. Since the operator enjoys a high-quality ultrasound monitor, the computer display is not looked at most of the time, and therefore needs little adjustment.

To be in **local work**, the operator has to press ‘Show’ (which is also the default on startup). This allows a preview of the examination ultrasound video, as it is seen on the ultrasound monitor. The ultrasound video will be in color if the computer was connected through the color video-out of the ultrasound device. When in this mode, pressing ‘Capture’, captures the displayed image and saves it in the patient’s file.

Since the operator’s hands are occupied, the ‘Capture’ button was defined to be always active. This enables the ‘Enter’ key, or a special hardware button mapped to it, to provide the capture functionality. This allows image capturing by the operator without needing to look at the computer display.

When the operator wants to pass to **remote work**, the expert is called. Once the session is established, the ultrasound window is displayed in large size, and both sides see it.

Pressing ‘Send All’, sends the expert all the images and clips taken so far during the examination. When in **remote work**, every time ‘Capture’ is pressed, the image is saved on the operator’s computer in full quality, and in parallel, sent to the expert’s computer using compression (lossless compression, unless requested differently).



Machine Name: Calling the Default Computer

Expert's Video ☑

11:22: 0. 40, Video State Changed - TRANSFERRING.

11:22: 0.260, Video State Changed - TRANSFERRING.

Figure 4: TeleUS-Operator interface

Expert Interface

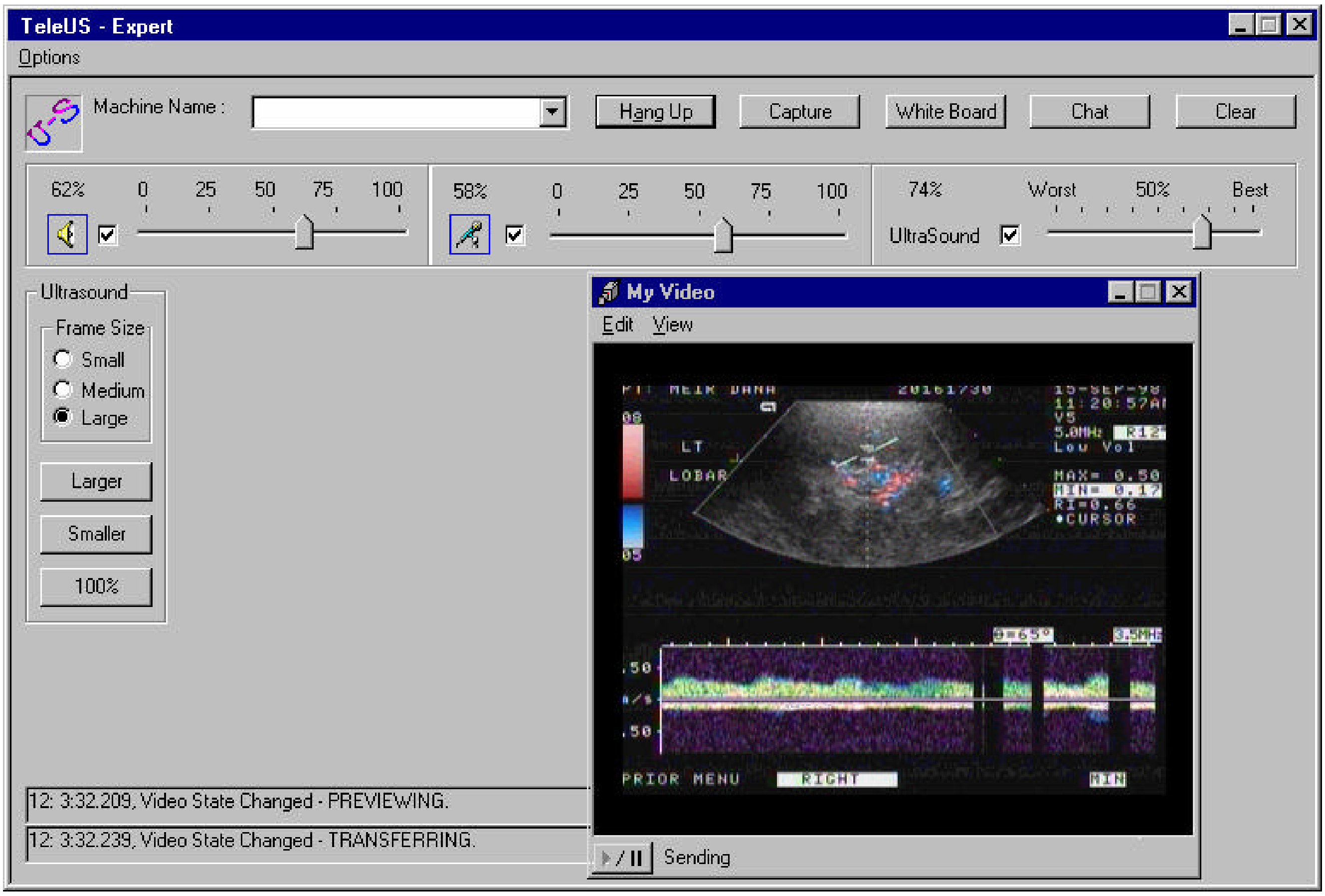
The TeleUS-Expert interface is presented in figure 5. Unlike the operator, the expert's hands are free. Thus, the interface designed gives the expert full control over all the system. In addition to the features available in TeleUS-Operator (except local work), the expert also has control over the ultrasound video, as follows:

1) Moving the ultrasound window or even hiding it.

2) Sizing the video resolution (frame size) by selecting the window size: Large (CIF), Medium (QCIF) or Small (SQCIF).

3) Sizing the video frame by pressing 'Larger', 'Smaller' or '100%'. Larger allows stretching the image (without changing resolution), Smaller shrinks the image and 100% brings it back to normal size.

4) Selecting the ultrasound video quality on a scale bar between highest quality (Best) and lowest quality (Worst). Higher quality means a low frame rate with high quality of images, while lower quality means a high frame rate with a high compression ratio that degrades the video image quality.



62% ☑

58% ☑

74% UltraSound ☑

○ Small
○ Medium
● Large

12: 3:32.209, Video State Changed - PREVIEWING.

12: 3:32.239, Video State Changed - TRANSFERRING.

Figure 5: TeleUS-Expert interface

The video in TeleUS-Expert is scaled and hence not of high quality. Consequently, the ‘Capture’ button in TeleUS-Expert remotely operates the capture functionality in TeleUS-Operator, causing a high-quality image to be sent to the expert interface.

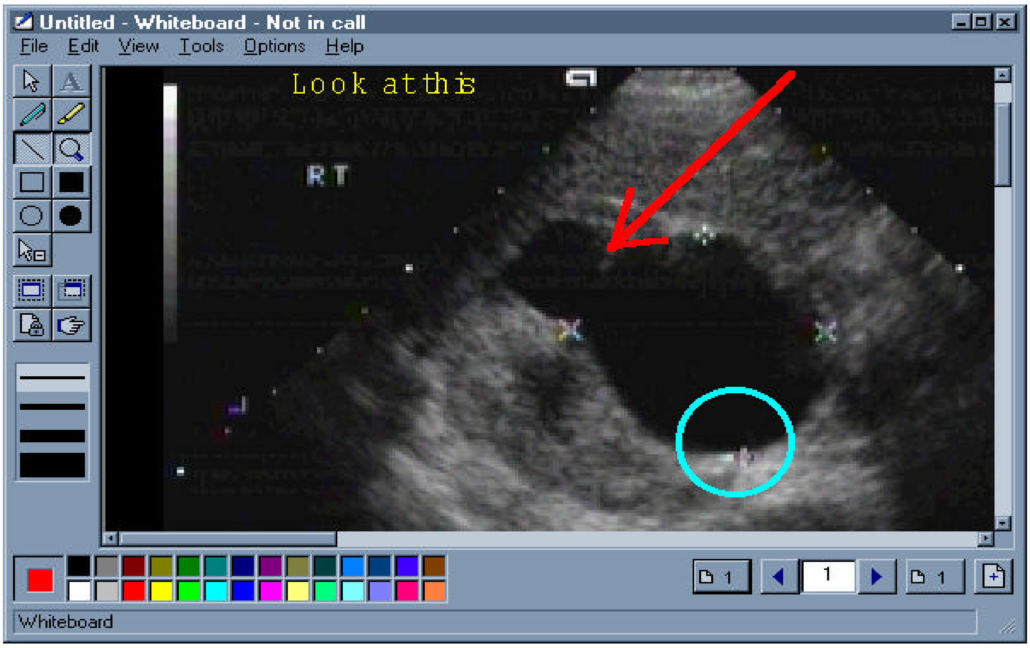


Figure 6: TeleUS Whiteboard

EXPERIMENTATION

TeleUS was tested by simulating a few communication environments and by running it in a working environment of the Tel-Hashomer ultrasound department [10]. The following paragraphs describe the simulations, experiments, and the results.

Simulations

The simulations tested the prototype in various communication environments such as LAN (not loaded), ISDN (connected through a router or dialup service) and POTS. The simulations setup included 2 PCs, connected through the communication infrastructure. One of the PCs was connected to a VCR with two different ultrasound tapes replayed. During these simulations [10], measures of the following parameters were taken: bandwidth in use, channel delay, frame rate (FPS), data transfer time (and file sizes), as well as audio, video and ultrasound quality.

Experiments in Tel-Hashomer

The Tel-Hashomer Hospital has a relatively big imaging division, with an ultrasound department having a staff of five sonographers, two physicians and a trainee physician. The department does internal ultrasound examinations for the hospital departments and for the emergency room.

During the morning hours, all the staff is in attendance, but during the afternoon, only one physician and one sonographer are at work. After working hours (evenings and nights), a sonographer and physician are on-call, while in the hospital there is only a trainee-on-duty, having no expertise in ultrasound.

We conducted a series of experiments with TeleUS at the hospital [10]. We set up the equipment at different rooms and tested it on the available communication infrastructures, i.e., LAN and POTS. The physicians and sonographers used and experienced TeleUS in various types of examinations. Following the experiments, they expressed their opinions on telesonography in general and on TeleUS in particular by filling in questionnaires.

Results

The performance of TeleUS [10], using each communication technology (note that ISDN 384K here is an extrapolation), is shown in figure 7. The communication technology and its bandwidth are given in the left two columns. The center columns present the transfer time of an ultrasound image and of a standard ultrasound sheet (12 images). The rightmost column is the video speed in FPS (Frames Per Second).

Communication Technology	Bandwidth	1 Image Transfer Time	1 Sheet (12 images) Transfer Time	Video Speed (FPS)
LAN	High	Marginal	8 seconds	up to 25
ISDN	384K	2 seconds	29 seconds	15
ISDN	128K	8 seconds	1:46 minutes	5
ISDN	64K	24 seconds	5:20 minutes	1
POTS	33.6K	40 seconds	10:40 minutes	0.45

Figure 7: Performance of TeleUS for different communication technologies

Images were captured in PAL resolution with high color (64K color depth), producing a 600K uncompressed file for each image. The effective compression ratio using lossless WinRAR varied for different examinations and in different parts of the same examination. The compression ratio was higher than 1:4, giving an average compressed image file size of 140K. An explanation for this relatively high compression ratio might be that ultrasound has low color distribution (ultrasound is mostly black and white with some red or blue colors for Doppler).

All the measures were taken while the system was transmitting also audio and video streams. Transfer time of all transmissions assumes lossless WinRAR compression. A sheet, containing 12 ultrasound images, is transmitted as one file. The video speed in FPS was measured when not sending files, and with the highest quality possible when using H.261/3 codecs.

When transferring images, the time measured included compression delays and channel initialization time. The transfer time of one image came out reasonable on the LAN, as was the time for 128K ISDN and higher (less than 8 seconds). It was too long, however, for the ISDN 64K and POTS (higher than 24 seconds). Transferring a sheet took just seconds for a bandwidth of 384K or higher, but minutes for a lower bandwidth. Note, however, that a sheet is transferred once, at the start of an examination, so its transfer time is not that critical.

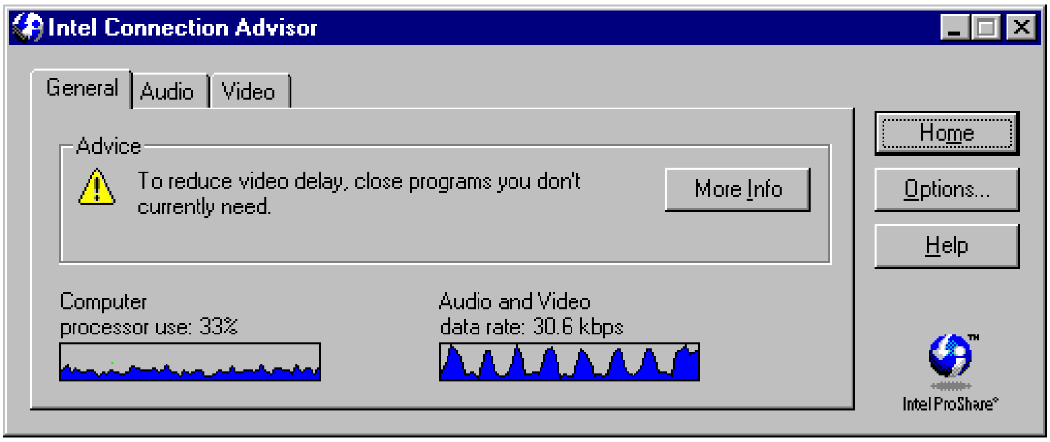
There is a significant difference in the image (and also sheet) transfer time when going from ISDN 64K to ISDN 128K. This difference, from 24 seconds to 8 seconds (3 times faster), can be explained based on the way NM allocates channel bandwidth. The audio channel in NM consumes around 32K of the overall bandwidth. Thus, leaving the file transfer a bandwidth of only 32K in ISDN 64K and but 96K in ISDN 128K. Note also that the ultrasound and video channels almost halt while the system is transferring files.

The video speed in FPS was measured under the following settings: H.261/3 protocols, CIF window size, maximum codec quality, and during audio transmission. Like for images, it varies for different examinations and in different parts of the same examination. The ultrasound video was relatively smooth, starting from 5 FPS upwards, on ISDN 128K and higher, but was not adequate at a lower bandwidth (see figure 7).

Since TeleUS uses the automatic channel distribution of NM, the video almost halts when file transfer occurs. Figure 8 presents the bandwidth allocated to the audio and video channels in POTS when transferring a series of files. The video/audio bandwidth looks ragged - getting lower whenever a file transfer occurs and returning back to normal when it ends.

Conclusions

The feedback received from the Tel-Hashomer Hospital experiments revealed that the medical staff is enthusiastic about telesonography. They found the TeleUS prototype friendly and efficient, having useful options, and even extremely appealing when running on a high bandwidth infrastructure.



To reduce video delay, close programs you don't currently need.

Computer processor use: 33%

Audio and Video data rate: 30.6 kbps

Figure 8: Intel Connection Advisor

Nonetheless, we reached several conclusions related to various multimedia, hardware, and software aspects. Concerning multimedia, we emphasize the following four conclusions:

1) Audio quality – since it is still not phone like, one needs to learn how to talk clearly and use continuous sentences rather than abrupt ones.

2) Resolution – there is a need for PAL resolution in transmitted images and for CIF in the ultrasound video.

3) Ultrasound video – in telesonography, the ultrasound video turned out to be most important, even if scaled, since it is useful for directing the operator, and it allows the expert to sense the examination environment.

4) Whiteboard tool – it supports well the kind of cooperative work needed between the operator and expert. For example, the ability to point out things on the images simplifies the remote work, making it more similar to regular local work. A similar ability for the video stream could enhance the cooperative work even more, making it more natural.

Some hardware-related conclusions, reached from the experiments, are:

- Special button – since the operator is busy handling the ultrasound device, operating also the PC at the same time is very difficult. Consequently, an experimental hardware button was used for image capturing during the experiment. It is recommended to connect or even integrate such a button into the ultrasound device.
- Headset – a cordless headset is a must, preferably a headset that covers only one ear, so that the sonographer can also tune-in to the environment.

- PC Placement in the Ultrasound Room – placing a PC in the ultrasound room was found to be a complicated task. First, the room is very small. Second, light from the computer display often bothers the sonographer used to darker conditions.

Regarding the NetMeeting software, we encountered the following drawbacks:

1) NM turned out to be unstable. It crashed for various reasons, it got the computer stuck or just plain slowed down the video connection after some time.

2) Its automatic channel allocation does not allow for specific control of the bandwidth needed for the different connections.

3) NM locks the video card, and so does not enable image capture from the card itself, but only from the video stream displayed on screen in CIF resolution. To capture a higher resolution image, one has to use a multi-user video card, such as the Winnov card, which costs more.

The next version of NM might solve the above problems or different SDKs could be experimented with. We now turn to a general discussion of our work.

DISCUSSION

The simulations done showed the applicability of telesonography and confirmed the design adequateness for the various communication technologies and the different work modes [10]. Figure 9 shows the connection quality for each communication technology:

- POTS – the quality of most connections is not adequate, though voice quality is above medium.
- ISDN 64K – the quality of most connections is adequade, but the ultrasound connection quality is bad.
- ISDN 128K – the quality of most connections is good, though the ultrasound connection is scaled and its quality is medium.
- ISDN 384K – the quality of most connections is good.
- LAN – all the connections are of very good quality.

	Communication Technology				
Connection	POTS 33.6K	ISDN 64K	ISDN 128K	ISDN 384K	LAN High
Information	Bad	Medium	Good	Very good	Very good
Voice	Medium-good	Good	Good	Good	Very good
Visual	Medium	Medium-good	Good	Good	Very good
Ultrasound	Bad	Bad	Medium-good	Good	Very good
Coordination	Very good	Very good	Very good	Very good	Very good

Figure 9: Connection quality for different communication technologies

In summary, per work mode:

- **Remote background work** is applicable in most communication technologies, though somewhat difficult in POTS.
- **Remote scaled work** can only be implemented using medium, or higher, bandwidth communication technologies, e.g., ISDN 128K. Even in this case, the scaling needed is rather significant.
- **Full remote work** is possible, as expected, only with use of a high bandwidth network such as LAN or ATM.

In conclusion, our generalized design for interactive telesonography proved itself as adequate for the specific environment of ultrasound examinations. However, until such a design is commercially implemented, widely deployed, and seamlessly assimilated in the medical environment, the full benefits of utilizing multimedia technologies for interactive telesonography will be hard to realize.

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