Remote consultation with a multiple screen FilmPlane radiology workstation

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ABSTRACT

As hospitals geographically spread and radiologic services are required in remote locations, the radiologist increasingly must conduct a remote practice. Rapid image transmission from the remote site to the radiologist is important but only half the problem. First, the radiologist may need to view and discuss the images with the technologist to verify image quality or to specify the location of follow-up images. Second, the radiologist may need to discuss the case with another radiologist for a second opinion or for the advice of a sub-specialist. Third, and most importantly, the radiologist may need to discuss the case with the referring physician to better understand the text data, clinical history, and referring physician's clinical questions and concerns, and to better convey the location and extent of the clinical findings.

In this paper we detail the requirements for a remote consultation workstation, present previous work on remote computer interaction, and describe the FilmPlane remote consultation workstation in detail. We then discuss the MICA medical communications project in which FilmPlane will be used for a remote consultation study between the UNC family medicine clinic and the main hospital 1/2 mile away.

1. BACKGROUND

1.1 Consultation in Radiology

Radiologists consult with radiologic technologists, other radiologists, and referring physicians. These discussions revolve around medical images, so they require both verbal and visual communication.

Radiologists may consult with technologists for several reasons. Radiologists generally supervise technologists so they may need to view the technologists' work before releasing the patients. Further, some radiologists, such as mammographers, must be able to review the films and communicate to the technologist which anatomy needs to be visualized on follow up films.

Radiologists may also consult with other radiologists for an expert or second opinion. Radiologists in general practice may wish to consult with a sub-specialist in a tertiary-care center to gather more information about a difficult case and sub-specialists may wish to consult with other radiologists to gather a second opinion or for periodic quality control. All this radiologist-to-radiologist communication will require each party to be able to talk with the other, to see a quality high resolution image, and – most importantly – allow each person to point out image features to the other.

Finally and most importantly, radiologists need to consult with referring physicians, such as family medicine clinicians in a remote rural clinic. First, a pre-interpretation consultation may be required. For example, a family medicine clinician may have a patient with a possible broken bone and request a quick "wet read" from the radiologist before releasing the patient. Second, a post-interpretation consultation may be used to allow the referring physician to better understand and visualize the interpretation results. Third, the surgeon may consult with the radiologist as part of the surgery planning process.

Thus a electronic radiology workstation must be able to provide context and detailed information to both the radiologist and consultation partner, must allow both parties to control the field of view and to point to particular anatomy, and must allow both to adjust contrast to enhance viewing various anatomical objects.

Verbal communication is essential between the consulting parties. The ability to see the face and gestures of the consulting partner, while not essential, would be desirable.

1.2 The FilmPlane Radiology Workstation

During the last six years, the UNC radiology workstation project has developed a series of FilmPlane radiology workstation prototypes[1]. FilmPlane uses a *microfiche* mental model to navigation over a large two-dimensional surface containing all the images in the patient's image folder (Figure 1). Each image study is organized into vertical strips with the newest study on the left. A *Navigation View* displays "postage stamp" miniatures of all the images in the patient's folder, with each study organized as a vertical strip of images. A *Viewport* shows a portion of the navigation view that can then be displayed at full resolution in the *Detail View*. The mouse can be used to drag the viewport to another portion of the navigation view to display other images at full resolution in the detail view. Additional function is provided to scroll the detail view up, down, left, and right.

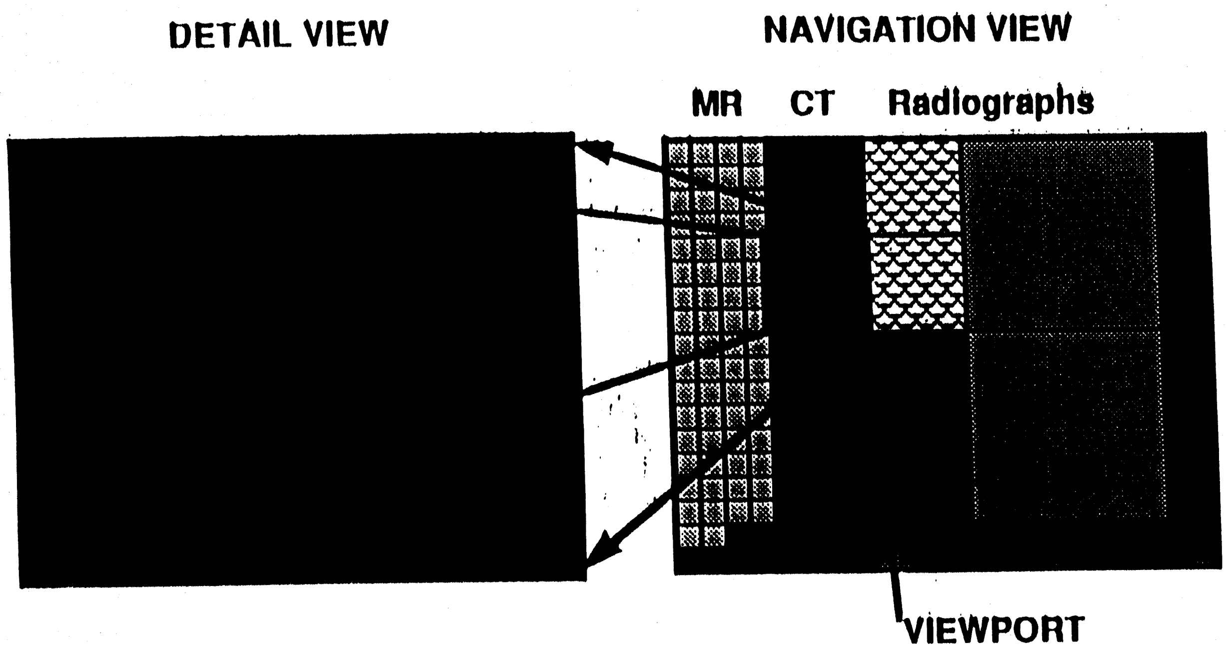

Figure 1
FilmPlane Navigation View, Detail View, and Viewport.

FilmPlaneII is implemented in C++ and the X windowing system under UNIX operating systems on Sun Microsystem and Digital Equipment workstations. One or more 8bit framebuffers can be connected to the workstation to provide a fairly low cost multiple-monitor interpretation environment. UNIX memory mapping is used to speed startup duration. There is exactly one viewport and corresponding detail view for each monitor attached to the workstation. Each monitor can be toggled by the user to show either the navigation view or the detail view corresponding to that monitor.

FilmPlaneII uses 12-bit CT, MRI, and plain film images in the UNC Image Library format[2]. Images are stored in the X client process in 12-bit per pixel form. Each image and study is associated with a look up table realizing a user-adjustable window width and level setting[3]. Every time an image is displayed, all the pixels in the image are put through the window width and level lookup table, moved into a buffer, transfered from the X client process into the X server process – using the X windows MIT shared memory extension software – and finally moved into the framebuffer for display. This process provides for a 1/2 screen scroll in about 1.1 seconds with a Sun SPARC 2 workstation. Figure 2 shows a two screen version of FilmPlaneII.

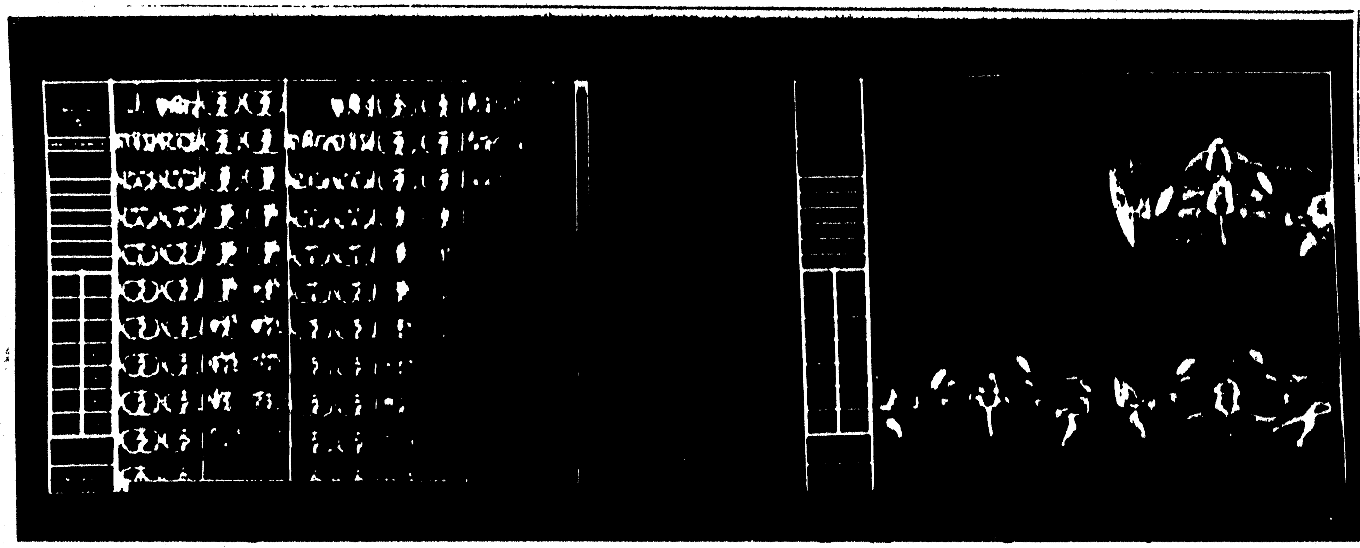

Figure 2
FilmPlane Navigation and Detail Views

1.3 Computer Supported Cooperative Work

Computer supported cooperative work (CSCW) is a growing area of interest within computer science in general, and human factors and computer human interaction (CHI) in particular, with an annual conference devoted to the topic.

A great deal of this work focuses on sharing visual information spaces. TeamWorkStation[4] and MERMAID[5] use workstation windows to show video images of collages during computer-supported video-conference. Other windows allow the sharing of information from drawing and writing packages, as well as other applications. The VideoWindow system[6] can link two remote rooms by providing an "electronically shared wall". The developers at Bell Core hope to make the users feel that the remote rooms are linked so well that they are almost a single room. Such technology might be useful to link radiologists in a hospital's reading room to their colleagues in another reading room in a remote clinic.

Other researchers have used anthropological or coordination[7] approaches to study the organizational personal, and interpersonal aspects of local cooperative work – both computer and non-computer supported – to gain an understanding of the requirements for CSCW systems.

2. REMOTE CONSULTATION WITH FILMPLANE II

A workstation for remote consultation about radiographs and other medical images will have to contain features from both shared-visual-information CSCW systems and radiology image-interpretation workstations. Like visual CSCW systems, the radiologists will need to talk with each other while looking and pointing at the visual information in the patient's folder. However, the remote consultation radiology workstation must also provide image navigation and viewing features including sufficient resolution for the radiologic task[1], appropriate preset and dynamic greyscale manipulation[8], a well-designed interface that minimizes radiologist cognitive load, sufficient display area and minimal response time. To reduce learning time and interference, the remote consultation workstation should be similar to that of the single-user radiology interpretation workstation.

To provide a remote radiologic consultation environment, we extended the FilmPlane II radiology workstation software to provide the ability to allow radiologists to share viewports and detail views, and to see the location of their colleague's cursors. FilmPlane II allows an arbitrary number of workstations to be configured into a multi-user remote consultation environment. Each workstation can have an arbitrary number of monitors. Monitors – or more precisely, the related detail views – are linked according to their left/right order and related to viewports in the navigation view. Figure 3 shows one possible configuration for a two-party consultation where both workstations each have three monitors.

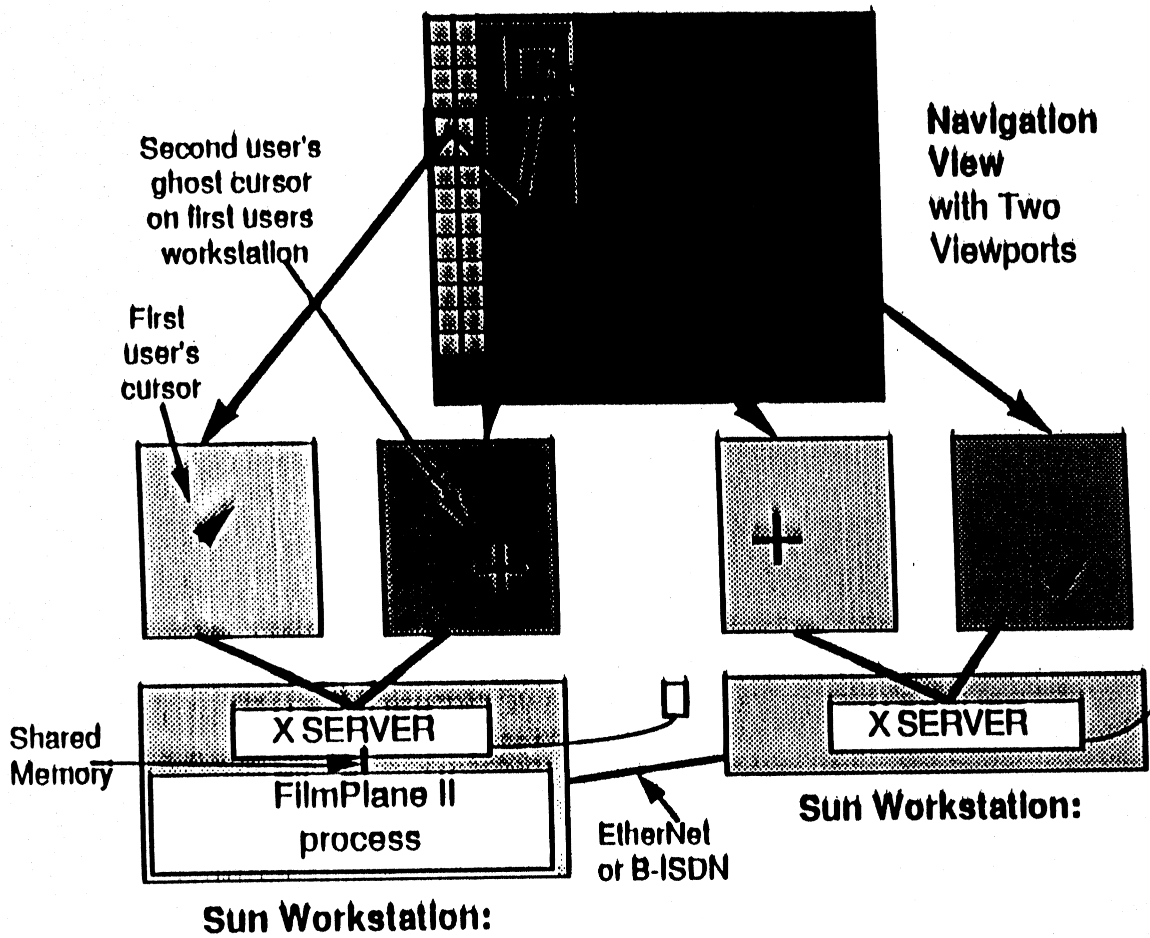

Figure 3
FilmPlane II configuration for remote consultation with two workstations, each with two monitors.

The consulting users need to be able to talk to each other. Verbal communication in our remote consultation environment is provided by conventional telephones with head sets to allow for hands-free operation. A real-time video image showing the consulting-partner's face could be made available in a separate monitor or eventually in an Xwindow.

The consulting users need to be able to indicate spatial locations on the images corresponding to verbal pronouns[9] (e.g. "look at this!"). Further, they need to be aware of the commands and actions the other user(s) are taking to be able to understand the behavior of their display screens. In short, the users need to be able to see the locations of the cursor of each of their consulting partners. Figure 3 shows each users' cursor as an arrow. However, each workstation also displays the location of the other user's cursor as a plus sign. These "ghost" cursors are implemented as tiny X windows that move in sync with the actual cursors from the other screens.

CSCW researchers have proposed a number of control mechanisms to allow multiple users to control a single application[9]. A "chalk-passing" mechanism is analogous to a number of co-workers using a single chalk board to facilitate a joint project. In this analogy, "passing the chalk" implies passing system control; a chalk-passing schema implies that only a single user controls the interaction at a given time.

However, the chalk-passing approach imposes a structure to the dialog that may get in the way of the consultation. Therefore, we have initially chosen to use a "Pandemonium" approach where any user can invoke any command at any time. This approach allows a more free flowing dialog, but may fail with certain consultative tasks or personalities. Field testing during the initial phase of the MICA project (detailed below) should allow us to determine which of these two methods will be most appropriate for radiologic consultation.

4. THE MICA PROJECT

4.1 Introduction

The Medical Information and Communications Application (MICA) project is a cooperative research project which will study and test concepts to allow effective human interaction in an environment where physicians and other individuals are in separate physician locations. Human interaction includes the exchange of both spoken and visual information. Effective interaction across distances require communications systems which provide sufficient utility in a number of mediums including voice, still images, and video.

The MICA project will conduct research into and demonstrate interactive consultation over distances using a public Broadband-ISDN communications network. The project will test some of the critical technologies and human factors essential for remote consultation. Under the MICA project, systems will be developed and tested to acquire, process, store, retrieve, and display medical image information among multiple locations. This research will be conducted at the University of North Carolina at Chapel Hill by the Biomedical Engineering Communications Research Facility and the UNC Department of Radiology with networking assistance from BellSouth Services and Fujitsu Network Switching.

4.2 Medical Application

The MICA project will take place in a clinical setting in the facilities of UNC and the UNC Hospitals. The Family Medicine Center is a recent addition to the UNC Hospital system. It has been established for patients who require a lower level of care than that provided at the core hospital. The Family medicine center is located at the periphery of the UNC campus, approximately one mile from the main hospital. The Family medicine Center has plain film equipment, but relies on radiologists located at the hospital for image interpretation. Today, this requires that the plain films be transported in batches in a van to the hospital. Patients may be sent home only to have to return the next day when a problem is discovered during interpretation. MICA will enable a radiologist to conduct a "wet read" and a patient's physician to study and review the films with a radiologist during the patient's visit.

In a typical scenario, conventional film-based radiographs will be taken and developed at the family medicine center. These films will then be fed into a film digitizer which converts the image into a 200 micron digital format. The digital representation of the image is fed through a local display workstation which accesses the B-ISDN network. A connection is established by the local workstation through the B-ISDN network to the archive workstation in the Biomedical Engineering department. The archive system processes the image into the proper format for storage and display purposes.

The radiologist, working at an image display workstation in the main hospital will retrieve an image or a series of images from the archive using the FilmPlane II radiology workstation and the B-ISDN network. Once the radiologist has examined the images, a connection will be established by the radiologist to the physician at the Family Medicine Center for a consultative session using the remote consultation features of FilmPlane II. During consultation, hand-free telephones or headsets will be used for voice contact.

4.3 Communications Network

A remote consultation system must have a communications network capable of transporting and switching high speed information over a wide geographic area. A primary objective of the MICA project is to demonstrate that a public switched B-ISDN network is well-matched to the stringent communications requirements of an interactive image-based consultation system.

Interactive consultative sessions require high speed communications to transfer the large amounts of information that define an image. The B-ISDN communications links used in MICA are capable of carrying information at data rates of up to 155 Mb/s. It is an objective of the MICA project to develop high speed communications protocols which support effective image and file transfers across the network.

The demonstration B-ISDN network is provided by BellSouth and Southern Bell in Chapel Hill in conjunction with Fujitsu Network Switching of American Inc. in Raleigh NC. A Fujitsu FEDEX-150 switching platform providing 155 Mb/s B-ISDN services is connected to the UNC hospitals complex through the Southern Bell Fiberoptics network. Two Sun workstations and a Sun SPARC 2 file server are linked between the Family Medicine Practice Center, the Department of Radiology, and the Department of Biomedical Engineering.

5. ACKNOWLEDGMENTS

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