#47

Reprinted from

INVESTIGATIVE RADIOLOGY

April 1991, Vol. 26, No. 4

Current Concepts

STEVEN E. SELTER, MD, *Editor*

Multimedia Communications Technology in Diagnostic Imaging

TERRENCE P. MCGARTY, PHD

DIAGNOSTIC IMAGING IS a blend of many processes: evaluating the results from a set of assessments on a patient, conferring with other sources and professionals, and providing the interpretation to an attending physician for appropriate subsequent use. In a microcosm, it brings together all elements of a multimedia environment, combining, in some cases, the use of text, images, video, voice, and even the movement of pointers as descriptors of the diagnostic approach. This combination of the viewing of and the commentary on a set of assessments of a patient is one way to understand multimedia communications. In essence, multimedia communications is the act of having one or several individuals interact with one or several data types, in several media, for the purpose of obtaining and transferring information.[1,2]

In diagnostic imaging, there currently are several trials that are attempting to extend these concepts to provide a fully integrated environment for not only image diagnostics but also for a fully integrated patient/hospital information management system. This review presents the results of some of the efforts under way among four major health care institutions in the Boston area and in conjunction with NYNEX and MIT. The institutions are Brigham and Women's Hospital, The Boston Childrens Hospital, Massachusetts General Hospital, and the New England Medical Center. Several of these institutions already have contemporary PACs systems for the storage and management of radiologic imaging and also have display devices for the presentation of images, text, and certain record data. The problem that is faced by the users, however, is that each is a standalone system, with its own special interfaces; the systems do not allow for ready dialogue between users. There has been extensive work by others in this area that have addressed similar issues but have not dealt with the total multimedia integration issue.[3]

Based on a close interaction with these four institutions, a common set of requirements evolved for a system that allowed the access to and manipulation of multimedia data by one or several users. First, the users required a systems approach that would allow for the development of applications, by themselves, and that could take advantage of the underlying capabilities of the multimedia communications services. Second, the system must allow for interfacing to a wide variety of data sets, including existing PACs systems, voice storage systems, high-density image jukebox storage systems, medical record systems, and other storage devices. Third, the system must allow for ease of communications between multiple users, where ease is defined by a natural interface that is consistent with a conversational approach in diagnostic conferencing and consultation. These three objectives were met in the design of the system.

What is Multimedia?

The term multimedia is used in many different contexts and is greatly misunderstood. In the current popular press, it is viewed as merely a set of mechanisms for the storage of

From NYNEX, White Plains, New York, and MIT, Cambridge, Massachusetts.

Reprint requests: Terrence P. McGarty, PhD, NYNEX, 2000 Corporate Drive, Orangeburg, NY 10962.

Received August 23, 1990, and accepted for publication, after revision, August 27, 1990.

different data types on a local basis and their display to a single user. In the extended view of multimedia communications, it is understood as an environment for the sharing of information in various forms (video, image, voice, text, records, etc) that are stored in different locations. Diagnostic imaging places significant challenges on the diagnostician, as well as the attending physician, and multimedia communications can assist in meeting this challenge. There is an increasing need for sets of physicians to act in concert in combining their talents for the best delivery of service to the patient.

Multimedia communications is characterized by the following factors:

- Multi sensory: it uses several of the human senses in transferring, processing, and creating information.
- Multi-user: it interconnects several users of the information into a conversational mode and allows a dialogue based on a fully interconnected set of media.
- Displaceable: it allows for the establishment of communications and information transfer that is displaced in both space and time from the source.
- Interactive: it permits a real-time interaction between any of the users of the medium, whether the users be human, databases, or applications software.

The multimedia environment is one that is user-centered and is designed to meet the users' needs in interfacing with complex images and in conveying information from one location to another. Multimedia is not just a description of how the data are stored, it is, more importantly, the description of a philosophy of human interaction with complex data elements in a multi-sensory fashion.

System Architecture

The current system architecture is shown in schematic form in Figure 1. It is composed of four layers that allow for the end user to easily develop and extend the applications that are resident on the system. The system was developed around two major guidelines. First, the system elements would be constructed along a set of standard interfaces that allow for ongoing development that might be impeded by a proprietary interface.[4] Second, the design is modular and allows for multiple layers of interface for the development of end-user application programs or for the expansion of the existing services. The combination of these two guidelines allows for a fully flexible system.[5] The system is composed of the following four layers.

Applications

This is the end-user layer that allows for the end-user to interact directly with the system. It is at this level that applications for radiologic review are operated, and that databases and systems such as PACs are supported.[6] Generally, in current radiologic systems, interconnection between such systems is done in a closed environment, namely, supported by a single vendor and with proprietary interfaces. The application layer interfaces with the next lower layer, with an application programming interface, through a set of calls that are named macros. These allow the application developer to construct applications without having to know the details of the underlying computer or communications resources. A PACs system may be addressed as easily as a voice storage system of the hospital information management system. This is facilitated by the construct of a compound multimedia object which in essence is an object-oriented data object used in a fully distributed data space.[7]

System Services

This layer of the architecture was developed to support the applications developer to provide ease of access to a fully networked communications environment that operates in an open fashion. The system services provide a client

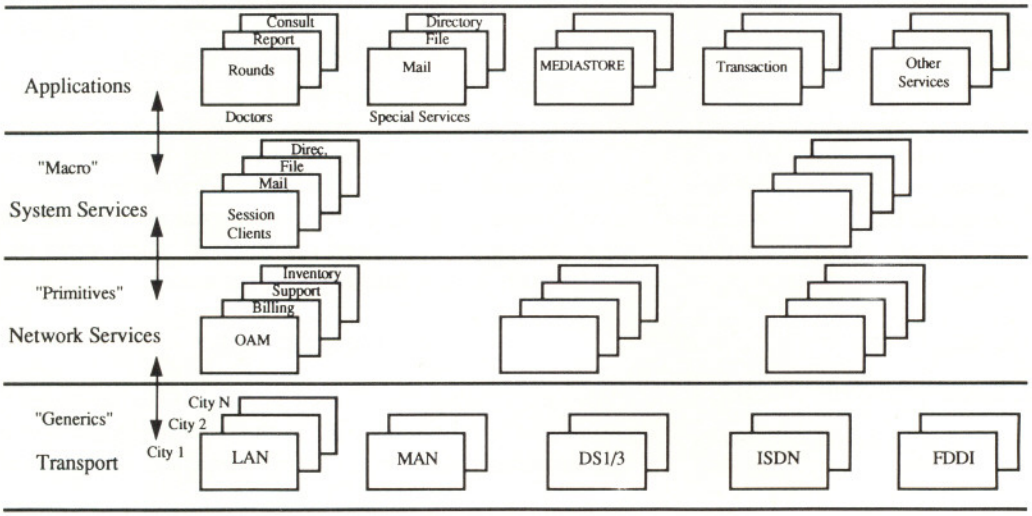

Fig. 1. Image networking products.

facility for distributed communications of multimedia objects. These objects allow for the combination of video, voice, text, image, and other multimedia entities into manipulable and processable data entities.[8] Listed below are are four underlying system services that are supported.

Session. The session service allows for the simultaneous and real-time interconnection of any application user into the system. Thus, a radiologist can attach one or several applications programs, bind one to several databases, and combine on this a voice and video conversation with several other physicians. The session service supports the synchronization of video, voice, image, and text; it controls the overall dialogue of the conversation; and it allows for the creation of activities that can be tracked by the system.[5,9]

File and Mail. The file and mail services allow for the filing and mailing of compound multimedia documents, thus allowing for the physically separate but logically joined storage, retrieval, and transmission of integrated video, voice, image, text, and pointer movement. Thus, the radiologist can file a report in voice and image, transcribe it into text, and retrieve it for review, consultation, and approval.

Directory. This is an access mechanism for the location of compound multimedia objects, applications, and users on the system. Retrieval and access to multimedia objects is now greatly simplified for both the radiologist and attending physician. It allows for a single point of reference for all information on a patient.

Network Services

The network services portion of the system architecture provides for the underlying support elements of the session server and the network management facilities. The positioning of the session server at this layer is based on the OSI Standards Organization requirement for placing session support of dialogue management, activity management, and synchronization below the other services layers.

Transport

The underlying transport of images must be done by a wide variety of mechanisms. Typical internal building transport of images is done by Ethernet, a 10-Mbps data link. Hospitals such as Brigham and Women's and Childrens have 100-Mbps FDDI networks that allow up to ten times the Ethernet rates. Inter-facility transport can be accomplished by the local telephone company's fiber network, as has been done in the Boston environment. In Boston, the facilities of New England Telephone are internetworked via a set of switched 45-Mbps fiber links. It should be noted that the typical high-resolution displays used are 2000 × 2000 pixels of 24 bits per pixel. This is approximately 100 Mbits per image. Thus the data rates allow for transport speeds of seconds.

The topology of the current system is shown in Figure 2. This depicts the overall network in Boston, showing the connection of the facilities of the four hospitals. The Massachusetts General facility interconnects several imaging centers that are located at remote facilities; the Childrens

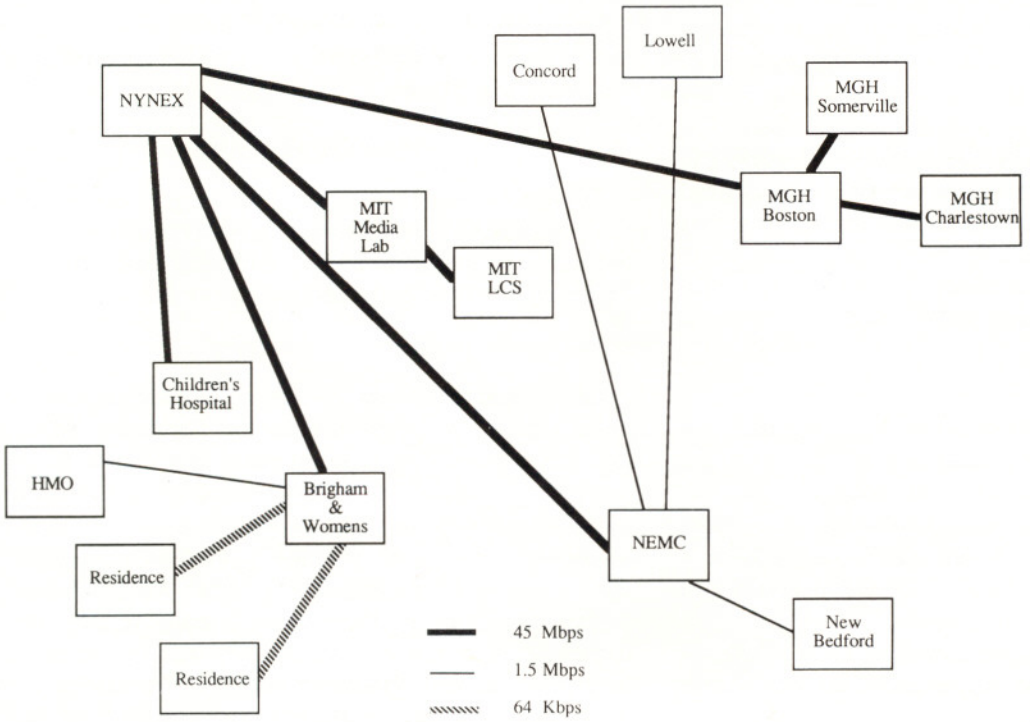

Fig. 2. Boston area medical trail.

facility is primarily internal; the Brigham and Women's has extended its facilities to physicians' offices; and the New England Medical Center has provided remote cardiology communications to several outlying hospitals.

Applications

The system now supports several imaging applications and there are several more that currently are under development. These applications range from nuclear medicine through surgical staging. The imaging applications now supported fall into the following three categories.

Image Analysis

The image analysis applications focus on the accessing and evaluation of information contained on images captured using plain film, magnetic resonance imaging, computed tomography, and nuclear medicine. The applications use existing infrastructures for capture and storage but use separate display terminals for the display, communications, and interaction functions. The specific applications operational are listed below.

Rounds

This application was developed at Childrens Hospital for the purpose of supporting attending physicians on the floor. The application brings up the patient's files and allows for access to the most recent radiologic images as well as the published transcription files. It permits voice annotation and supports annotation of images by mouse movement and text.

Report

This application is the backbone application that has been in testing for over a year. It consists of an environment focused on the image specialist that permits the physician to recover, analyze, process, annotate, and respond to images that are the result of one or several diagnostic tests. The current application supports voice annotation of x-rays and allows for the transcription and release of the transcribed version to other physicians. The application has been first used in nuclear medicine and has been expanded for use in radiology, urology, and neurology. It also has been provided with an interface to support direct access to PACs and other storage devices.

Consult

This application allows for real-time remote consultation between a radiologist and an attending physician. It has been initially focused in the area of cardiology, at New England Medical Center, allowing for the capture, storage, retrieval, and display of catheterization studies done in a full motion video format, allowing for the localization of stenosis of the cardiovascular system.

These three applications are supported on UNIX-based platforms and also run on Apple MAC stations (Apple Computer, Palo Alto, CA).

Image Processing

The advances in workstation design have allowed for the processing of radiologic images at local stations for the purposes of both enhancement and analysis. One specific application is the generation of three-dimensional images from sets of two-dimensional data. A specific application is in the area of surgical planning and staging.

Surgical Staging

In the areas of neurosurgery and maxillofacial surgery, the staging of the surgery is essential to minimize surgical time, morbidity, and mortality. To do this, a system has been developed at Brigham and Women's Hospital, using the underlying system services that allows the two surgical experts to plan and rehearse their surgical procedures using data generated from standard magnetic resonance imaging scans. The results indicate significant reductions in surgical time.

Integrated Transaction/Imaging

There is an increased demand for the management of not only the images but for the integration of patient care with billing and collection. This is the heart of a transaction-oriented image management system. In this case, the system in Boston has integrated both internal and external transaction-based systems into a single workstation to provide all billing information, as well as to create the billing electronic transaction and ensure that it is processed. The system uses the transaction interface provided by Probity and allows direct connection to Medicare and other third-party providers. This has allowed for better working capital management to be performed in the radiology department and other departments.

Future Developments

The current operations of the system provide for services that are integrable into existing operations, but more importantly, it also provides a test bed for the development of future applications. Some of these are as follows.

Interactive Three-Dimensional Imaging

On the Boston network, MIT has connected the Connection Machine (Thinking Machines, Inc, Cambridge, MA), a fast image-processing supercomputer that allows for the processing of data from multiple radiologic sources. Currently, this system can take two-dimensional data from a single modality and provide a manipulable three-dimensional rendering. It will be possible, through both the processing power and the conformal mapping techniques developed, to combine multi-modality data (computed tomography, magnetic resonance imaging, positron-emission tomography, etc) into the same three-dimensional image.[10]

Interactive Surgical Facilitation

Imaging has been used for surgical planning and also for surgical staging. It is now possible to perform the tasks of surgical facilitation in situ, in the surgical theater, using real-time imaging modalities, and providing both the processing and display technology to the surgeon during the actual surgery.

Education and Training

Multimedia training systems have been developed by various medical schools under the direction of faculty members. Harvard, Cornell, and Columbia are currently working with the NYNEX consortium to develop, integrate, and operate a fully distributed regional medical educational system using image, video, voice, and text.

Radiologic Office Systems

The system also has the capability of connecting physicians to the network at their offices, as well as in the hospital environment. As part of the trial with Brigham and Women's Hospital, there will be a set of direct connections using the ISDN (Integrated Services Digital Network) service supporting 64-Kbps circuits. This will allow for the direct viewing of images by radiologists in a remote location, enhancing the capability to cover emergency rooms at off hours.

New Radiologic Services (cost containment and increased patient flow)

One of the major driving factors in the development of these systems is the need for better cost containment, as well as the ability to increase patient flow across existing facilities.[11,12] The ability to remotely process and evaluate radiologic studies opens the way for the consolidation of professional resources, while having the image capture performed at multiple locations.[2] Thus, it is possible to have large hospitals perform this function in a more cost-effective way for Health Maintenance Organizations and similar organizations.

Acknowledgments

The author thanks David Margulies, MD, and Ted Treves, MD, of Childrens Hospital; James Thrall, MD, and Jaime Taffe of Massachusetts General Hospital; Deeb Salem, MD, and Rich Brenner, PhD, of New England Medical Center; Ethan Fenner, Bob Greenes, MD, and Frank Jolescz, MD, of Brigham and Women's Hospital; and John LaPook, MD, of Columbia Presbyterian Hospital and President of Probity for their cooperation, support, and insight into the operations of a user-driven system.

References

1. McGarty TP. Multimedia Communications. New York, NY: John R. Wiley & Sons; 1991;127–132.
2. McKinlay JB. Technology and the Future of Health Care. Cambridge, MA: MIT Press; 1982;75–81.
3. Goldberg M. A multimedia medical communications link between a radiology department and an emergency department. J Digit Imaging 1989;2:179–181.
4. Prior FW, Nabijee KH. Information management for data retrieval in a picture archive and communications system. J Digit Imaging 1989;2:31–38.
5. McGarty TP. Multimedia session management. IEEE J Commun (in press).
6. Mun SK. Image Management and Communications. Los Alimitos, CA: IEEE Press; 1990;332–340.
7. Roger E, et al. Image organization and navigational strategies for radiological work station. J Digit Imaging 1990;2:79–80.
8. Pizer SM, Beard DV. Medical image work stations. J Digit Imaging 1990;2:321–324.
9. Little TDC, Ghafoor A. Synchronization and storage models for multimedia objects. IEEE J Select Areas Commun 1990;8:713–721.
10. Bowmans M, et al. 3-D segmentation of MR images of the head for 3-D display. IEEE Trans Med Imaging 1990;9:321–330.
11. Anderson GF. Providing Hospital Services. Baltimore, MD: Hopkins Press; 1990;117–120.
12. Davis K. Health Care Cost Containment. Baltimore, MD: Hopkins Press; 1990;217–220.