Editorial

FROM MULTIMODALITY DIGITAL IMAGING TO MULTIMEDIA PATIENT RECORD

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Abstract—The constant improvement in computer power and performance nowadays offers convenient and efficient means of manipulating images, graphics, and movies on off-the-shelf workstations. With this improvement the trend toward integration of multimodality clinical documents from patient records comes naturally. Images and graphs are certainly the most important part of the complementary information that must accompany the text and numerical data. It is, however, possible to include sounds and voice messages together with all the other modalities. In medicine that could certainly help conveying heart murmur or sounds, but could also offer a convenient way of including vocal messages and comments. These new possibilities will certainly change the way physicians use workstations for direct communication. The computer industry will soon offer means of interactive communication between remote users through computer workstations. That alone will open a completely new era in cooperative computing and remote consultation scenarios in medicine. More than the technology itself, a complete change in behavior and work habits can be expected in the medical community.

Key Words: Multimedia, Digital imaging, Information systems, Medical record

Recently I hired a young undergraduate student who was recommended to me for a summer job in computer programming in our Digital Imaging Lab. The project that I assigned him was to develop a simple interactive program for browsing through sets of teaching medical images presented as quizzes with multiple choice questions. The second day after he started working on this project, he invited two friends of his to participate in the project. When I passed by his desk he introduced them to me. One of them was an artist who specializes in computer graphics, and the other was a musician who uses computers for composing and playing music. When I asked them why such a team for a simple computer project, they answered that they work as a team because they believe that a good software program must have nice graphic presentation and must be punctuated with music and sounds.

Is this a typical example of the younger generation that lived through the era of video games and computer animation? In fact, I think that there is more to it than just that. It is a clear demonstration that computers have become more than just terminals through which one can access and manipulate documents and data. Integration of graphic animation, sounds, and data is a natural combination that can be handled by most modern computers. It is then comprehensible that the younger generations find it very natural to use computers for handling text, sounds, graphics, and animation. To really move toward using multimedia appropriately, we should stop being ecstatic every time we see a rotating three dimensional object on a graphic workstation and start realizing that there is much more that can be done with today's computers. This is true in the medical area as well as any other domain. The time has come to grasp the new computer capabilities and to adapt them to our daily needs. What is lacking so far is a real understanding of the clinical work flow and medical scenarios to clearly identify the user needs and requirements. Such understanding is essential for appropriate design of computer applications in order to offer the right tools to the users.

Recent projects in Europe have approached this problem through systematic evaluation of the clinical work flow. Among other projects funded by the EEC, the EuriPACS project (1) has extensively worked on this type of problem and tried to establish functional models to design systems that are more adapted to the clinical reality. Computer models have been developed (2) to describe in detail the functional and operational model of radiological data flow and clinical operations related to these data and information. Such models should help us to better understand the real needs and to better design the related software and management tools.
MULTIMEDIA MEDICAL RECORD

The rapid development of computerized information systems and medical informatics provides access to a variety of documents in different forms. In particular, a large number of medical data are generated in form of static or dynamic sets of images. Clinical investigations rely more and more on imaging modalities, and clinicians are faced with the difficult task of integrating very large amounts of data from increasingly complex imaging techniques. The user must be able to visualize and compare images from different imaging modalities and to correlate what can be observed on these images with the rest of the clinical and ancillary data. Multimodality workstations capable of handling all these data on a convenient and practical platform will soon become a necessary tool for practicing physicians. The first step toward such workstations is achieved through appropriate management of images from different imaging modalities, together with the rest of the medical data. It has become widely recognized that the real added value of computerized imaging management and communication systems (IMAC) comes from the integration of images and image related data with the rest of the clinical data that constitute the medical record (3, 4).

The content of a medical record consists of data provided from different investigation techniques as well as collections of notes, reports, and observations (see Fig. 1). The medical record also contains chronological observations as well as treatment plans. The completeness of the medical record that should contain all the medical and therapeutic events of a patient's lifetime is essential for adequate patient care. A computerized patient record must therefore offer this completeness to fulfill the clinician's needs. It must handle multimedia data from different sources (text, sounds, physiological signals, and images) but it must also offer a coherent link between all these data. The tools offered to the users to browse through these data and visualize them in a convenient way is as important as the quality of the data themselves. Clinical users must be able to access these data in a natural and convenient way that matches the convenience of paper-based medical records.

MEDICAL DATABASES AND MEDICAL ARCHIVES

The architecture of hospital information systems (HIS) capable of handling data related to patient medical records have for a long time been based on a centralized topology. Apart from a few exceptions, most of the early systems were designed to regroup all the data in a centralized archive from which the patient record or at least parts of it could be consulted. In the recent years, a trend toward distributing the information over a large number of archive units has emerged (5). This second generation in HIS architecture is clearly influenced by the evolution of computer technology that now offers the possibility of handling data from different databases within a single application. The distributed architecture allows a modular and progressive evolution of large HIS. The same concepts apply to Picture Archiving and Communication Systems (PACS). As soon as a large volume of data are to be archived and retrieved from different locations simultaneously, it becomes more efficient to distribute different data in separate locations.

A distributed system, however, requires sophisticated traffic management to maintain efficient data distribution and adequate response time. Prefetching algorithms must be developed to retrieve the data of patient's medical records from different archive locations. These data must also be available to different users in different locations. In addition, access rights must be accounted for to customize the data integration and provide different users with different "profiles" of the same data. The term "profile" is used here to define different presentations of the same data of a medical record and to provide different views of the same data or parts of the data to different users. An orthopedic surgeon will need a different profile than a radiologist or a cardiologist. They all need to ultimately access all of the patient's record, but through different aspects with different priorities set to different parts of the record. These requirements not only affect the way data are presented to the user, but also the way they are extracted from different databases. Specific users' needs will dictate the way and the extent of data that must be retrieved. This certainly applies to medical images as well. Subsets of image sets that are acquired in different imaging procedures might be quite sufficient to clinical users, while the whole set is indispensable to the radiologist who is making a primary diagnosis. Quantitative data contained in an image might be irrelevant to an internist while they could be essential to a cardiologist or a radiotherapist.

The data presentation must also be adapted to different users' needs. This is particularly true for multimedia records containing graphics, images, and texts. It is certainly true for medical images where large sets of data must be presented. For referring physicians and clinicians, a concise presentation focused on the pathological findings is desirable. The integration with text documents and reports is essential. For surgeons and physicians performing invasive interventions, a three-dimensional approach that can provide a better perception of complex anatomical structures in space
Fig. 1. Schematic diagram showing the medical data flow around the patient record. Adapted from Lemke et al. (4).

is often needed. For radiologists who perform the primary interpretation of the radiological images, a high resolution workstation allowing simultaneous display of images from different imaging modalities is preferred.

**MEDICAL WORKSTATION**

The development of workstations capable of handling medical data in different forms such as text, graphics, images, and sounds requires careful user-interface design to be easily accessible by clinicians and noncomputer-oriented users. Effective management of medical images from different imaging modalities is the first step toward the integration of multimedia information. It is also the most challenging part because the amount of data obtained in the form of images is much larger than text, graphic, or sound elements. The proportion of clinical investigations based on imaging modalities is also constantly increasing. Image display and manipulation on graphic workstations is certainly a technical challenge. The major difficulty comes from the large size of the image data and the high performance required to display and manipulate them in a convenient way. Two papers presented in this special issue have focused on this problematic aspect of workstation design. The project under development at university of Berlin is defining and implementing the basis for multimedia workstations in a medical environment. The OSIRIS software developed at the University Hospital of Geneva focuses on the management and presentation of medical images from different imaging modalities on a variety of workstations. It is being used as part of a hospital-wide PACS directly integrated with a distributed HIS (6).

The components required for a multimodality workstation are becoming widely available on today's computer systems. Most systems can handle high-resolution graphics, sounds, and animation. The challenge is to properly use these capabilities. Software and hardware capable of handling animated images can be used in a large number of applications in medical imaging.

Conversely, some multimedia capabilities available on most of today's computer systems are not always appropriate for handling all types of medical images. The particularity of medical images is that they
require a higher dynamic range than most other, nonmedical, graphic applications. A typical medical image contains data that are 10, 12, or 16 bits deep corresponding to 1024, 4096, or 65536 gray levels. This dynamic range is usually not supported in most multimedia systems. These systems are more often geared toward video animation and tend to support images with a large number of colors (16 million colors on 24 bit RGB systems) but only 256 shades of gray. In order to properly visualize medical images, special software (or hardware) tools are necessary to allow the user to interactively adjust the window of gray levels of an image that are displayed at a given time. This is particularly true for radiologists and other clinicians responsible for primary diagnosis tasks for which they need the full information contained in a medical image.

Another aspect of multimedia workstations in a clinical environment is their accessibility. Physicians and nurses tend to move frequently from one location to another and do not have a fixed workspace where they spend most of their time. Therefore a single personal workstation on a desk is often not enough and one has to provide the clinical users with workstations distributed in different locations of their work environment. In order to become really useful and efficient, access to the patient record must be possible hospital-wide all the way to the bedside. The wide distribution of workstations capable of accessing data from different distributed archive systems requires appropriate management of data flow and an efficient networking system. Portable and movable workstations have often been proposed to allow users to place the workstations in different locations where they are needed when they are needed. Hand-held systems as well as notebook computers connected to database servers through wireless networks are expected to become really handy in a busy clinical environment. However, fixed workstations will remain in areas where user interactions with the system require more complex and repetitive tasks. Primary interpretation of radiological studies, as well as quantitative analysis of the images, are bound to be performed in a fixed location on high resolution workstations especially tailored for these tasks.

**MEDICAL NETWORKS**

As mentioned earlier, the difficulty of setting up a distributed HIS and PACS resides in the complex task of distributing the information to the users in multiple locations. This requires appropriate usage of high performance networks. The network topology and the effective throughput must be carefully planned to ensure adequate response time. Although high speed networks can provide very high data throughput, a wide distribution of large amounts of data cannot rely only on a single network. Multi-tiered networks combining different networks with different bandwidths are necessary. In order to obtain the best performance, it is necessary to separate the data traffic into multiple local networks in different sections of a large institution. Incoming data must also be separated from data being distributed to remote consultation stations. In a distributed architecture, the traffic between different database servers and file servers must be optimised to allow for better communication between these servers, independently from the data acquisition and distribution workload. It is often difficult to accurately predict the real needs in traffic throughput for a given system in a given environment. This is particularly difficult when dealing with images because the volume of data is several orders of magnitude higher than the one necessary for text and numerical data. Several computer simulation techniques have been proposed in an attempt to create realistic models of PACS networks. However, these models are often simplified and limited to a very particular setting representing a subset of an institutional wide network. Besides, it is difficult to accurately predict the workload variability related to a nonuniform access to the data by large numbers of users at different times. Accurate planning of large medical networks requires a combination of both computer simulations and experimental measurements. As far as images are concerned, recent observations tend to show that different network performance is required in different tasks of an IMAC system. Data acquisition and archive is usually fairly constant in data rate, which can easily be handled by relatively low performance networks. Traffic between database servers requires higher throughput that should not suffer from degradation of performance when the data rate increases. The most unpredictable parts of the network are the segments responsible for data distribution to display workstations, especially in a multimedia environment where the exact proportion of images and text required at different times by different users can vary considerably. Depending on the clinical task they have to perform, users may have different requirements. In some instances, the workload can be handled through relatively slow networks such as Ethernet, and in other cases the data throughput must be one or two orders of magnitude higher to allow for rapid transmission of very large amounts of image data. A schematic representation of a simple multi-tier network combining different networks with different data throughput is shown in Fig. 2.

In combination with high speed networks, rapid transmission of large amounts of data can also be
achieved through data compression. The largest amount of data that can benefit from data compression in a patient record are the images. Images can be compressed either through reversible lossless compression or through lossy compression. Lossless compression algorithms can only achieve relatively low compression rates (ratios of 2 to 1 up to 4 to 1). Lossless compression algorithms can provide much higher compression rates. However, through lossy compression, images are slightly degraded. The challenge is to determine the amount of image degradation that is applicable without affecting the diagnostic quality of the images. Recent studies have demonstrated that large images, such as chest X-rays, could be compressed using full frame discrete cosine transform (DCT) at a rate of 10 to 1 without affecting the diagnostic quality of the images (9). An alteration in diagnostic quality was found at around a ratio of 20 to 1 for these images. These compression techniques remain quite sparsely used because they are computationally intensive and they require special hardware implementation to be applicable to large images in clinical routine. Besides, these techniques require extensive clinical evaluation experiments to determine the degree of compression that is applicable without interference with the clinical diagnosis. To be statistically significant, these experiments must be carried out using a large number of images from different modalities with different clinical findings that must be evaluated by a large number of observers (10). While these clinical trials were still underway, several new developments occurred in the area of data compression. These developments come from a rapid evolution of the television and movie industry toward digital solutions. New compression algorithms have been developed and implemented with much higher compression ratios than the simple full frame DCT. Besides, a combined progress in the computer industry and in digital video and data communication have led to new hardware solutions based on these new compression algorithms. Some of these new concepts in image compression are discussed in the paper by Cicconi et al. in this special issue. It is predicted that some of these new developments in the area of image compression will rapidly be applicable to medical imaging systems.

**COMPUTER ASSISTED DIAGNOSIS**

The extension of computerized medical records and the access to clinical data through multimodality workstations will certainly have a significant impact on physicians' work habits and will change the way they practice medicine. Medical informatics tools will soon become part of everyday medical practice. It is therefore natural to foresee that efforts will be developed to provide the medical users with advanced tools to assist them in data analysis, knowledge finding, and decision making. With the development of digital imaging techniques in medicine, quantitative analysis techniques have emerged in a large number of appli-
cations. Data extracted from the images as well as appropriate image processing techniques can assist radiologists and clinicians in providing more accurate, objective, and reproducible image interpretation. Furthermore, the integration of data obtained from different imaging procedures as well as other clinical investigations can provide the user with a better synthetic view of the data. However, the increasing number of highly specialized investigation techniques often leave healthcare providers with the very difficult task of matching all the results into a coherent clinical diagnosis. Computer-assisted interpretation of these data can help the clinician by providing the appropriate interpretation criteria and by matching them with epidemiological and statistical data as well as relevant diagnostic rules obtained from knowledge databases.

Other domains that are extending beyond diagnostic assistance are the computer simulation domain and the virtual reality domain. Computer simulation can help analyze and predict physical and physiological phenomenons. They have been widely and successfully used in areas such as biochemistry, microbiology, physiology, and pathophysiology. Similar tools are expected to become very useful in clinical practice as well. They should help in predicting clinical evolution and effects of therapeutic interventions based on statistical and rule-based models. Such tools are designed to help answer “what if?...” questions in complex situations based on concrete statistical data and sophisticated models. They are expected to become more widely used in everyday practice as soon as the clinical data and the statistical and knowledge databases become directly available in computer-accessible form.

Similarly, computer graphic simulations, also known as virtual reality tools, can now provide very powerful means for exploring three-dimensional anatomical and physiological phenomenon. Although we are still a few years away from being able to practice a complex surgical intervention through computer simulation before performing it in the real world, some preliminary developments have already shown very promising results. The paper presented in this special issue by Thalmann et al. clearly shows the trend of new computer assistance is slowly becoming omnipresent in medicine and healthcare. Recent developments in the computer industry have taught us not to expect big revolutionary changes in technology but rather to look for progressive and constant improvement in performance and capabilities of computer systems. We can expect to move into tomorrow’s world without really noticing it. What seems today a technological breakthrough, such as being able to manipulate multimedia documents on a single workstation, will soon become part of our daily world. It will only make the usage of hospital information systems and clinical workstations more natural and user-friendly.

As a last remark, I would like to state that multimedia communication and information systems will come into our daily lives whether we want them or not. It is our task now to clearly identify the areas and applications where this new technology can help us in everyday practice. It is also important to adapt multimedia applications to the users’ needs rather than watch the users progressively adapt themselves to a technology-driven evolution of their environment.

REFERENCES


About the Author—Osmann Ratib is a certified cardiologist who received his M.D. degree from the University of Geneva in Switzerland in 1979. Dr. Ratib has been working in the field of medical imaging for the past ten years and has authored many publications on digital cardiac imaging applications. He received a Ph.D. degree in Medical Imaging at the Department of Radiological Sciences at UCLA in 1989. He is currently in charge of the development of a Radiological Picture Archiving and Communication System (PACS) at the University Hospital of Geneva.