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Image Engine: An Integrated Multimedia Clinical Information System

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Image Engine is a microcomputer-based system for the integration, storage, retrieval, and sharing of digitized clinical images. The system seeks to address the problem of integrating a wide range of clinically important images with the text-based electronic patient record. Rather than create a single, integrated database system for all clinical data, we are developing a separate image database system that creates real-time, dynamic links to other network-based clinical databases. To the user, this system will present an integrated multimedia representation of the patient record, providing access to both the image and text-based data required for effective clinical decision making.

1. Introduction

The rapid growth of diagnostic imaging technologies over the past two decades has significantly increased the amount of non-textual data entering the patient record. In addition, many medical specialties such as Dermatology, Ophthalmology, and Pathology generate clinically important images. Clinical images are often difficult for the clinician to access and often impossible to integrate with other relevant clinical data [1]. Systems for the classification, retrieval, and integration of clinical images are in their infancy [2]. Traditional Picture Archival and Communications Systems (PACS) [3-5] are generally expensive, monolithic solutions that primarily serve the needs of radiologists and are often not well integrated with other clinical information systems. New clinical imaging technologies demand innovative medical image database models that can integrate all patient data. Such systems may improve the quality of patient care [6,7], increase the patient's involvement in clinical decision making [8,9], and may produce significant new medical knowledge [10].

There is currently a confluence of developments that makes it technologically and financially feasible to implement institutional systems integrating digitized clinical images from a wide variety of sources with the traditional medical record. These innovations include inexpensive microcomputer workstations with the processing power, memory, and display characteristics necessary to permit real-time decompression and display of high resolution digital still images and digital video. Image compression technology [11] is now widely and inexpensively available, and international compression standards are emerging. Digital video technology is now an integrated part of a number of many microcomputer operating systems and permits us, for the first time, to display real-time, on-screen color video sequences using widely available and affordable computers. Networking advances increasingly supply the necessary bandwidth for institutional transport of compressed digital images.

2. Image Engine

Image Engine [12] is a microcomputer-based system for the storage, retrieval, integration, and sharing of a wide range of clinically important digital images. In addition, Image Engine will integrate image data with patient data from the University of Pittsburgh Medical Center's (UPMC) text-based, Medical ARchival System (MARS) [13] clinical information system. The development of Image Engine is supported by a contract from the United States National Library of Medicine's (NLM) High Performance Computing and Communications (HPCC) program.

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The Image Engine System architecture consists of three layers: 1) an Image Server, 2) an Object Database, and 3) an Image Browser client application. In addition, Image Engine will make use of two network-based services: the MARS clinical information system and the PINDEX indexing server. Image Engine uses a network-based, client-server architecture, which supports multiple, simultaneous user sessions via standard Ethernet and TCP/IP.

3. The Image Server

The Image Engine Server consists of a dedicated server computer and a number of gigabyte range hard disks connected to UPMC's high speed data network. These disks store digitized, compressed clinical images. Still digital images are stored in the PICT format; digital video images are stored as Quicktime files. PICT files are compressed using the ISO's Joint Photographic Experts Group (JPEG) [14,15] still image compression algorithm. Digital video files are compressed with the proposed ISO Motion Picture Experts Group (MPEG) video compression scheme [16].

4. The Image Object Database

The Image Object Database uses a hybrid relational/object-oriented database model [17] to represent the images stored on the Image Engine Server. Each image is represented by an "image object" record in the object database. These image records contain information linking patient, physician, procedure, and image data. The database will be indexed using NLM's Unified Medical Language System (UMLS) Metathesaurus. The database may be viewed as a virtual database [18] in that it integrates data stored both locally and (by reference) on other clinical information systems. This approach has a number of advantages, including avoiding storage replication and problems with data version inconsistencies. Dynamic linkage to related clinical data in the MARS system is implemented by the automatic creation and execution of MARS queries from data stored in the Object Database.

5. The Image Engine Browser Layer

The Image Engine Browser (Figure 1) is a client application that allows one to interact with the Object Database through an easy to use graphical user interface. The Browser communicates with the Object Database over the network and uses a client-server model to request and retrieve image and patient data. Currently the project's workstations are based on Apple Power Macintosh 7100/66 RISC systems with 24 megabytes of RAM and 20 inch , 1152x870 pixel resolution color monitors using accelerated 24-bit color video cards.

Users may search for image sets using combinations of image properties including Metathesaurus terms. Retrieved subset summaries of images can be viewed as either a scrollable list of thumbnail images (100x100 pixel scaled, 24-bit color images) and/or a text list of object identifiers (image name, type, patient ID, etc.). Images can be selected and viewed at full or scaled size on the computer display in resizable, scrollable windows. Multiple images can be viewed simultaneously. Image information text can be viewed simultaneously with images. Retrieved image sets can be sorted and displayed on a number of criteria.

Digital video images can be displayed on screen and controlled with videotape-like features (e.g., reverse, fast forward, still frame, and reverse/forward frame capabilities). Users can convert digital video frames to digital still images.

The browser will provide a set of basic image processing functions to support image enhancement, image format translation, and feature measurements. In addition, the Image Engine Browser will communicate with and pass images to external applications such as image processors and electronic mail clients.

6. Networking Protocols

The Image Engine server is connected to UPMC's network via a high speed Ethernet connector and communicates with Image Engine Client workstations at UPMC via a proprietary message passing scheme using Apple Computer's Ethertalk networking protocol. We plan to switch to the standard Internet Protocol (TCP/IP) at a later phase of this project. The UPMC data network consists of a basic backbone of three FDDI rings using fiber optic cable with fiber optic limbs to collapsed Ethernet backbones in each of the constituent hospitals and clinics of the medical center. Fiber optic cable now extends to most hospital and clinic floors with standard 10BaseT cabling to individual workstations.

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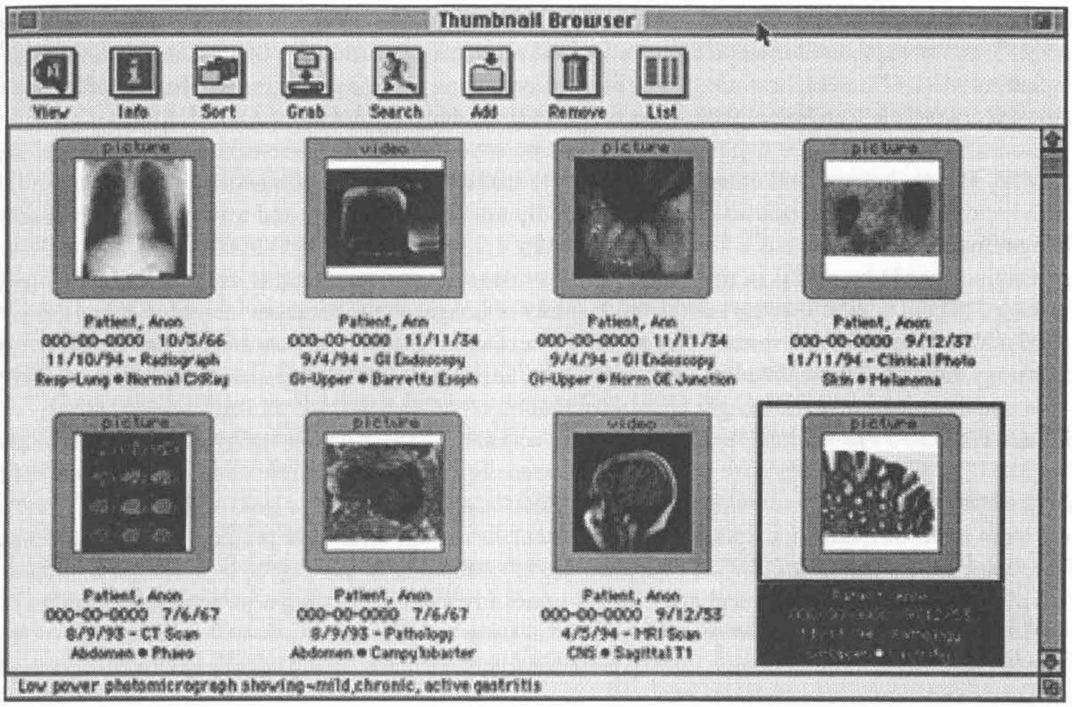

Figure 1. Image Engine Thumbnail Browser

7. Dynamic Links to the MARS Clinical Information System

The MARS database system supports a scripting language, called ESP, which we will use to implement dynamic links between clinical images in the Image Engine database and associated patient information in the MARS database. Using ESP, an application on the UPMC data network can establish a TCP/IP connection to the MARS ESP server and transmit MARS queries written in the ESP language. MARS patient data retrieved by an ESP query is returned over the network to the requesting application in a format defined in the ESP query script. ESP, therefore, allows an application to become a MARS client.

8. Indexing Images

We have developed a system called Pindex (Probabilistic indexing) which takes as input a string of free text and returns an associated list of MeSH terms that are each annotated with a probability of relevance. The development of Pindex has been supported in large part by the National Library of Medicine UMLS project. We are modifying and extending Pindex for the task of indexing images. We plan to use this modified version of Pindex to (1) index medical images based on their free text descriptions, and (2) assist a user in retrieving images given free text input from the user about the type of images that are desired.

9. Clinical Applications

We plan to initially install and evaluate Image Engine workstations in three clinical environments at UPMC: Clinical Pathology, Gastroenterology, and Medical Oncology.

In Clinical Pathology we will focus on issues involved in digitizing, compressing, indexing, storing, and retrieving both gross and microscopic pathology images. Clinicians in the Gastroenterology and Oncology test sites will identify pathology specimens (e.g.,, biopsies obtained during gastrointestinal endoscopy or diagnostic oncology procedures) from patients entered into the Image Engine database. These pathology specimens will be digitized, indexed, and added to the database. Image Engine will automatically integrate these pathology images with other digitized images (such as endoscopy, radiology, etc.) and the text-based clinical record for that patient.

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In Gastroenterology, we will work with clinicians specializing in fiber optic endoscopy of the gastrointestinal and biliary tracts. These domains will involve digital still and video images, pathology images, and radiological imaging studies (including MRI, CT, and Ultrasound). For patients entered in the Image Engine database it will be possible for clinicians to selectively view and manipulate integrated image and textual data.

In Medical Oncology, we will explore how one manages and integrates the wide range of images (including radiology, MRI, CT, pathology, and clinical photography) that are used in the diagnosis, staging, and treatment of patients with solid tumors. Clinicians will be able to rapidly retrieve both image and textual data for patients entered into the Image Engine database.

Image Engine should be useful in many other image-intensive clinical domains such as Dermatology [19] and Ophthalmology [20]. In addition, as the number and variety of images in the database increases, it has the potential to become a valuable educational and research resource. For example, it would be possible for one to retrieve and view a set of pathology, dermatology, ophthalmology, endoscopy, and radiological images for a given disease entity. Alternatively, one could retrieve selected images from a population of patients with certain characteristics.

It has been estimated that medical imaging databases acquire in excess of one terabyte of information per year in a major hospital [21]. Given the large size of even compressed digital images, we have chosen to limit our initial HPCC evaluation domains to a relatively small population of clinicians and patients. Our goal in this project is not to implement a very large scale, hospital wide, image database system during this three-year project. Also, Image Engine is not intended to compete with or replace PACS, which we see as continuing to develop as a radiological support system. Instead, we plan to focus on the technical and clinical issues involved in creating a potentially portable system that could be scaled to handle the image storage, retrieval, and sharing needs of clinicians, with an emphasis on integrating a wide range of clinically important images with the text-based patient record using relatively inexpensive, high performance computers and networking technology.

10. Acknowledgments

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