Seamless Multiresolution Display of Portable Wavelet-Compressed Images

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Image storage, display, and distribution have been difficult problems in radiology for many years. As improvements in technology have changed the nature of the storage and display media, demand for image portability, faster image acquisition, and flexible image distribution is driving the development of responsive systems. Technology, such as the wavelet-based multiresolution seamless image database (MrSID) portable image format (PIF), is enabling image management solutions that address the shifting "point-of-care." The MrSID PIF employs seamless, multi-resolution technology, which allows the viewer to determine the size of the image to be viewed, as well as the position of the viewing area within the image dataset. In addition the MrSID PIF allows control of the compression ratio of decompressed images. This capability offers the advantage of very rapid image recall from storage devices and portability for rapid transmission and distribution using the internet or wide-area networks. For example, in teleradiology, the radiologist or other physician desiring to view images at a remote location has full flexibility in being able to choose a quick display of an overview image, a complete display of a full diagnostic quality image, or both without compromising communication bandwidth. The MrSID algorithm will satisfy Joint Photographic Experts Group (JPEG) 2000 standards, thereby being compatible with future versions of the Digital Imaging and Communications in Medicine (DICOM) standard for image data compression.

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Image STORAGE, display, and distribution have been difficult problems in radiology for many years. The fragile glass plates originally used to store images were replaced by flammable celluloid, which was superseded more recently by stable x-ray film. As improvements in technology changed the nature of the storage and display media, the demand for improved image access and distribution have emerged as necessities in the dynamic environment of radiology today.

Digital imaging technology is supporting and enabling solutions within this new environment, although imaging and image management, itself, has not become less complex. Now increasing demand for image portability, faster image acquisition, and flexible image distribution is driving the development of responsive systems that utilize internet-based technology(ies). This has led to more use of online storage, because other methods are less permanent and more difficult to access, and

to an increasing interest in image compression.¹⁻⁵ Radiology is responding to the influence of the shifting "point-of-care" that has emerged over the last decade.

Parallel to radiology's environmental evolution, significant improvements in the capability of imaging devices create larger images (digital data density), require higher resolution, produce more images per examination, and lead to more examinations per study. Often, the newer images also use more shades of gray than the older image format, so they require more archival storage space. Thus, the amount of image information stored for ready access continually increases, yet there are still severe limitations in image portability, communication bandwidth, and storage device size. In the typical imaging system, the problems of storage, communication, and workstation capacity are addressed relatively independently. Although the systems are designed to make all components work together, each subsystem is also designed to be self-contained. This promotes some interchange of subsystems, which has been further supported by the institution of the Digital Imaging and Communications in Medicine (DICOM) standard.

Finally, digital technology has also raised issues regarding appropriate methods for viewing images. Images have grown from the 64×64 matrix of pixels used in early nuclear medicine devices to display matrixes of $7,000 \times 7,000$ pixels, as demonstrated at a technical exhibit during the meeting of the Radiological Society of North America (RSNA '98). The cost, size, weight, and heat dissipation required to display a 7K matrix at full resolution, with optimal brightness, requires workstation monitors that are so expensive as to make this task prohibitive for most. Therefore, techniques are being developed to view large-matrix images on commonly available monitors by increasing software capability, rather than upgrading hardware.

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REVIEW OF PREVIOUS WORK

There have been efforts to address several of these problems simultaneously, and they have led to creative solutions. For instance, Behlen et al⁶ developed a system of hierarchical data storage that allowed a medium-resolution image to be quickly recalled from the storage media and displayed. If the viewer wished to see a high-resolution image, the additional information could be recalled from the storage device to give a full-resolution image. This workstation design enabled optimal display of many low-resolution images quickly, which presented a large amount of context information to the radiologist. The radiologist could then magnify one or more images and scroll them across the screen at full resolution to view the full image detail.

This two-phase approach allowed the system designers to take into consideration the type of workstation monitor and the communication bandwidth available, as well as the speed of disk storage, all in an integrated way. They could design the nature and amount of image compression to match the bandwidth of the communication channel and deliver an image that matched the capability of the monitor. Unfortunately, this high level of integration required the use of nonstandard data structures, and DICOM-compliant workstations dependent on external interfaces.

The new Joint Photographic Expert Group (JPEG) 2000 data compression standard will make it possible to design flexibility into the image data compression algorithm, so that optimal integration can be achieved in a system based on international standards for image data format and communication. Because of the benefits of widely used international standards, the DICOM Committee is expected to adopt the JPEG 2000 as the DICOM standard, which will make JPEG 2000 widely used in the medical imaging community.

MULTIRESOLUTION SEAMLESS IMAGE DATABASE PORTABLE IMAGE FORMAT

Multiresolution seamless image database (MrSID) Portable Image Format, marketed by LizardTech (Seattle, WA), offers radiology robust image management solutions and options. Originally developed for processing satellite images and mapping, it is an imaging environment that includes a wavelet compressor. It employs seamless, multiresolution technology, which allows the viewer to determine the size of the image to be

viewed, as well as the position of the viewing area within the image dataset.

In the mapping environment, a user may first look at an overview of the entire region, then quickly zoom to a specific area using selective decompression. Pan and zoom commands automatically adjust the magnification and the position of center of the image within the entire map, as necessary. The user can quickly scroll these high-resolution images in any direction. Because of the method used to store compressed image data coefficients, the image decompression algorithms can also quickly expand the pixels in the adjacent field of view.

This seamless, multiresolution design is similar to the functionality of the standard film alternator, whereby the radiologist first establishes an overview of up to eight sheets of film, which allows a quick review of the entire data set. The radiologist can then concentrate on one or two films, perhaps by leaning forward to get closer to the images and to increase the spatial resolution and focus on a particular area. This model of a reading session is inherently multiresolution, because the radiologist focuses attention, in addition to some changes in apparent magnification because of the shorter viewing distance. It is seamless, because the entire range of images is visible to the radiologist at one time. The radiologist also has direct visual control over transitions from one portion of the image to another, or from one image to another.

Duplicating these convenient features of an alternator in a soft-copy viewing environment is technically not feasible because practical limitations restrict workstations to between one and three display monitors. However, a functional duplication of this capability can be constructed, as was shown by Paul Chang and colleagues during RSNA '98.⁷ Their demonstration used a workstation monitor where the images of greatest utility were transmitted first, and other images were transmitted and cached while the radiologist was viewing the first image or set of images. Although image data compression was not a prominent feature of their demonstration, it is supported by their techniques.

APPLICATION SOLUTION

LizardTech is tuning its MrSID Portable Image Format to the medical imaging environment. In addition to the multiresolution capability, the Portable Image Format has the capability to control the compression ratio of decompressed images. This can allow the user to compress all images in an

essentially lossless manner, with a relatively low compression ratio, perhaps 3:1. Then, when an image is viewed, it can be recalled first at a relatively low matrix size—perhaps $800 \times 1,000$ for a chest radiograph—but with a high-compression ratio of about 80:1. This approach offers the advantage of rapid recall of the image from the storage device and portability for rapid transmission and distribution using the internet or wide-area networks.

After viewing the image, the radiologist can choose to either increase the matrix size of the image on the screen (although this may decrease the field of view on a smaller monitor), or to decrease the compression ratio by requesting that the computer transmit more accurate information for each pixel presently displayed. Alternatively, the radiologist can choose to make both changes simultaneously, which will increase both the image resolution and the image fidelity at that same time. The advantages of this system are archival storage of images in a lossless manner with recall of images with full image fidelity for clinical, research, or medico-legal reasons. This provides the benefit of fast image communication when viewing images at lower spatial resolutions, yet with higher compression ratios in routine circumstances.

MrSID Portable Image Format can also be optimized for other image modalities, such as computed tomography (CT) scanning, where a matrix of images may be compressed simultaneously, allowing greater fidelity and compression ratios than are possible with single images. Because of the multiresolution capability of the technology, the system architects can design it to allow the single image of greatest interest to be transmitted first, followed by some of the surrounding images, followed by the rest of the images at one-slice intervals, if required. This provides the benefits of managing a large number of images

simultaneously, with higher quality and higher compression ratios, while retaining the benefit of random image access. It is not necessary to have a large amount of data storage capability nor to decompress the entire matrix of images to access one single image, because of the way in which the coefficients are stored in the MrSID Portable Image Format.

LizardTech's technology is readily adaptable to images with more than 8 bits of data per pixel on a monochrome display, as well as images in color. The method used to produce images always uses some information from the entire image, which allows for the construction of high-quality "fingerprint" images for image navigation. These images can be improved either in matrix size or in reconstruction fidelity by transmitting more coefficients. The MrSID algorithm will satisfy JPEG 2000 standards, thereby being compatible with future versions of the DICOM standard for image data compression.

FUTURE APPLICATION OF MRSID PORTABLE IMAGE FORMAT

The standardized, multiresolution capability of MrSID Portable Image Format makes it ideal for use in teleradiology, and able to support telemedicine applications. In teleradiology, the radiologist or other physician desiring to view images at a remote location has full flexibility in being able to choose a quick display of an overview image, a complete display of a full diagnostic quality image, or both without compromising communication bandwidth by transmitting variations of the same image twice. This technique is also useful in telemedicine, where still radiographic images may be transmitted to support the patient care encounter and diagnostic and therapeutic processes. It is anticipated that a future version of MrSID Portable Image Format will also support video.

REFERENCES

1. Srintzis MG: A review of compression methods for medical images in PACS. *Int J Med Inf* 52:159-65, 1998
2. Mitra S, Yang S, Kustov V: Wavelet-based vector quantization for high-fidelity compression and fast transmission of medical images. *J Digit Imaging* 11:24-30, 1998 (suppl 2)
3. Egashira K, Nakata H, Watanabe H, et al: Clinical evaluation of irreversible data compression for computed radiography of the chest. *J Digit Imaging* 11:176-181, 1998
4. Pilgram TK, Slone RM, Muka E, et al: Perceived fidelity of compressed and reconstructed radiological images: A preliminary exploration of compression, luminance, and viewing distance. *J Digit Imaging* 11:168-175, 1998
5. Harpen MD: An introduction to wavelet theory and application for the radiological physicist. *Med Phys* 25:1985-1993, 1998
6. Behlen FM, Hoffmann KR, MacMahon H, et al: Multiresolution storage in a PACS archive. *Proc SPIE* 3035:39-46, 1997
7. Chang PJ, Huffman J, Betancourt C, et al: Dynamic transfer syntax: A flexible representation and interactive image data delivery protocol for enterprise-wide image distribution and integration. *RSNA '98, infoRAD, Space CDA9203*