# Desktop Publishing and Medical Imaging: Paper as Hardcopy Medium for Digital Images

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**Desktop-publishing software and hardware has progressed to the point that many widely used word-processing programs are capable of printing high-quality digital images with many shades of gray from black to white. Accordingly, it should be relatively easy to print digital medical images on paper for reports, instructional materials, and in research notes. Components were assembled that were necessary for extracting image data from medical imaging devices and converting the data to a form usable by word-processing software. A system incorporating these components was implemented in a medical setting and has been operating for 18 months. The use of this system by medical staff has been monitored.**


**KEY WORDS: hardcopy, desktop publishing, digital image, image file format.**

IN THE MEDICAL IMAGING field, there has been considerable interest in and movement toward totally digital imaging and image management in a filmless environment.[1-4] Current emphasis on reducing the use of film and other hardcopy is one possible reason that paper has been overlooked as a hardcopy medium. The capability for paper output of digital images has only recently become widely and easily obtainable. Desktop-publishing software is now available that is capable of storing and printing good-quality, gray-value images.

Paper might seem to be an added and inferior redundancy to film and/or videotapes. In fact, paper offers an economical and flexible medium that allows images to be used for tasks that previously have not included image display, such as patient report generation, student and employee instruction, and record keeping in medical research.

This report describes how paper output of images can be accomplished in general and how it is accomplished specifically in the author's venue in a medical school hospital. The most frequent uses of paper display in this setting will also be described.

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## TERMINOLOGY

*Personal computer (PC).* A PC is any of the desktop microcomputers widely available for use in word processing, graphics, spreadsheet composition, and database management. The two most common types are (1) IBM-compatible machines made by International Business Machines (Purchase, NY) or a large number of other manufacturers such as Compaq, Zenith, NCR, Tandy, etc and (2) Macintosh computers made by Apple Computer (Cupertino, CA).

*Local area network (LAN).* A LAN is a communication network that allows access from many personal computers (within a small area) to common-function devices such as hard disks and printers. This allows electronic transmitting of data between computers. Components of such networks are generally a small cable, special boards in each computer, special software in each computer, and a central "server" computer to manage network functions and provide large amounts of disk storage.

*Digital image file format (DIFF).* A DIFF is any of the many standard file formats used for storing digital image data. This data can be subdivided into two types: (1) pixel intensity values (gray values) and (2) associated information such as patient demographics and imaging parameters. The files are stored on a computer disk (hard disk, floppy disk, laser disk). Formats include relatively popular, widely used types (eg, tagged interchange file format (TIFF), PIC, MacPaint, encapsulated postscript [EPS]) as well as relatively complex, proprietary formats used exclusively on medical imaging systems from a particular manufacturer. The latter type includes many formats conforming to the ACR-NEMA American College of Radiology/National Electrical Manufacturers Association (ACR-NEMA) standard and its planned replacement, Digital Imaging and Communications in Medicine (DICOM).[5-7]

*Gray-value image.* A gray-value image is an image composed of the signal intensities of the pixels. There is no color information. The number of intensity values (gray values) is most often a power of two, commonly 128 (7 bits), 256 (8 bits), 4,096 (12 bits), and 65,536 (16 bits). This term is used to distinguish between (1) colorless images that have a range of intensity values (gray value) and (2) colorless images with only two intensity values (binary). Both types of images are commonly referred to as "black and white" in everyday usage. The necessary differences in the handling of such image types on a computer has required the adoption of terms to distinguish them.

## GENERAL REQUIREMENTS

Printing of digital, gray-value images on paper requires (1) an accessible digital image file and (2) a software package with the graphics capabilities for loading an image file into a document file and printing the file. Recent years have seen the appearance and proliferation of desktop publishing graphics programs that can be used to create computer files that include both text and illustrations. Each graphics program uses a specific format of image file (eg, TIFF, EPS, MacPaint), a fact that has led to the development of programs for interconverting files so that an image generated by one system can be converted to another system's format. An important extension of these developments is that widely used word-processing programs have now begun to include graphics modules that use many of the available formats.

Accordingly, personal computers that can run current word-processing software have the potential to be used for paper display of digital images. Specialized desktop publishing software and hardware is no longer necessary for manipulating images on a daily basis. Word-processing software can now be used to load many types of digital image files, incorporate them into printed documents, and print good-quality images with appropriate text on paper for easy and inexpensive distribution.

Printing digital medical images using a commercial word-processing package requires the following steps: (1) obtaining image data from the imaging system, (2) converting data into a compatible image format, (3) loading data into a word-processing document, and (4) printing a document on a laser printer or plotter (Fig 1). The architecture of the imaging system is important. Many (but not all) digital imaging systems lack capabilities for communication with other computers and computer components. These systems have no communications ports (that can be connected to a LAN) or external (floppy) disk drives (that can output a file to a disk that can be carried to another machine). In these cases, extraction of image data must be done by acquisition through a separate hardware device such as a frame grabber or film scanner. These methods for obtaining medical images for a personal computer have been recently described.[7] This approach is somewhat time intensive and tends to reduce the ease and economy offered by paper printout.

Imaging systems that have communication

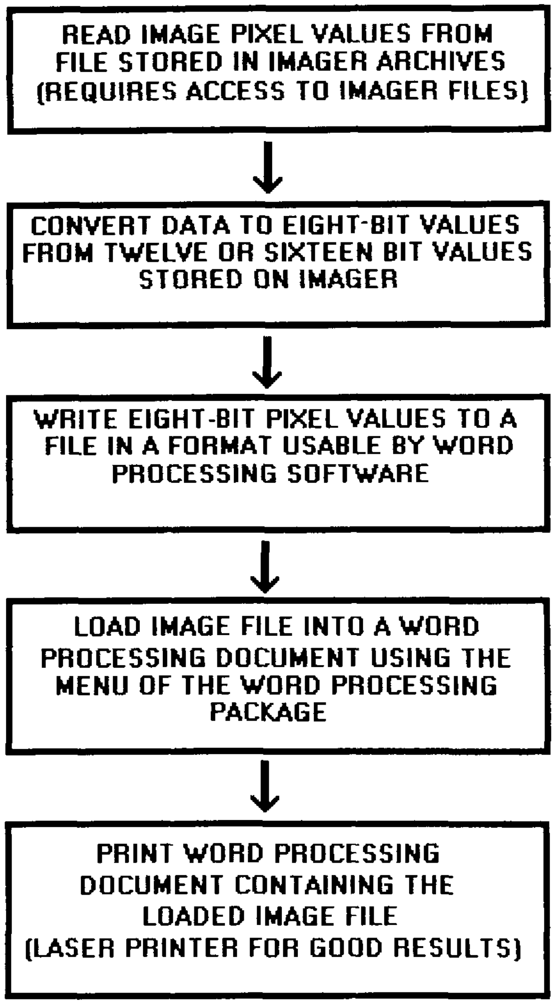


**Fig 1.** Flow chart of the strategy for paper printout of a digital medical image.

facilities allow direct access to archived digital image files. Some of these systems store image files in a proprietary or nonstandard format following the general ACR-NEMA protocol. To insure reliable and flexible image storage, retrieval and handling, this protocol specifies what information and capabilities a medical image file must have rather than specifying precise locations and patterns of data storage. ACR-NEMA files contain much larger amounts of patient data and image handling information (data-base information) than is usually found in general-use image formats such as TIFF.

For these reasons, reading image pixel data from ACR-NEMA files is not straightforward. However, because data are stored in groups, each containing subgroups called elements, pixel values will occupy a single section of storage, locatable using the appropriate group and element numbers, 7fe0 (hex), and 0010 (hex), respectively. Thus, location and reading can be implemented using very simple computer programs. Once a file is created containing only ordered pixel data, converting to standard formats such as TIFF or EPS is straightforward using commercial programs.

The central problem for data transfer from ACR-NEMA files is the general lack of provision for such transfer by manufacturers. This situation, noted by others,[7-9] appears somewhat baffling considering the simplicity of the steps necessary for data access. Because only pixel data is extracted by this process, no proprietary format or programming needs to be shown. This author knows of only two possible exceptions to this lack of access software: JIPS, (Philips Medical Systems of North America, Shelton, CT) and a Macintosh-based system to be offered by Picker (Picker International, Highland Heights, OH). Both packages appear to include a much broader array of functions than the simple image output discussed here. For the system to be described below, a small program was designed specifically for the magnetic resonance (MR) database to be accessed.

In some cases, an imaging system may provide computer access to image files in a format compatible with a word-processing program. In these cases, the file may be simply copied to a convenient location for further processing.

Pixel intensity data in most digital images is stored as 12- or 16-bit integers. The files used by word-processing software generally must be in 8-bit format. A choice must be made as to which 8 bits of the original data will be the most useful in image display on paper. For imagers which produce images of relatively constant brightness, this choice can be made once, and will consist of truncating or rounding off of the numbers in the original file. For imaging systems which produce a variety of brightnesses, each new image can be handled differently depending on the range of intensity values within that image. This latter type of data conversion has been well described in a recent report.[9]

In most cases, truncation or rounding leads to little loss of information. Because the range of intensities in any one image is usually only a fraction of the maximum possible range provided by the imaging system, the discarded information will be either zeros or noise.

The end product of image data conversion will be a digital image file (1) containing only pixel data with 8 bits per image pixel, and (2) in a location (a floppy or hard disk) that can be accessed through a LAN. Because this file is not a part of an image archiving or image database system, it does not need to contain patient or other information.

Once image data is in a file containing only image pixel intensities in an 8-bit format, it is ready to be converted to a format compatible with a particular word-processing program. Such a conversion is generally a matter of adding appropriate information to the file in the form of a "header," a few lines of data inserted into the file in front of the pixel data. Image file formats such as TIFF, EPS, and PIC, etc are published and can easily be followed in converting from a headerless file containing only pixel data. Some commercial image processing and handling packages (eg. Hijaak, Inset Systems, Brookfield, CT) can also make such conversions. After the image file has been converted, it is incorporated in a word-processing document using the menu of the particular program used. It can be printed with or without text or manipulated in much the same way as ordinary word-processor documents.

## AN IMPLEMENTATION EXAMPLE

At the South Carolina Children's Heart Center, a paper hardcopy system was implemented for MR images to determine whether such a resource would be useful and in demand in a medical setting. Although some interest in such a system existed before its implementation, there was no strong feeling that it would actually be used with any frequency. At the present time, paper hardcopy for MR images has been available for approximately 18 months.

MR imaging is performed on a 0.5 Tesla imager (T5, Philips Medical Systems). As provided by the manufacturer, this imaging system (Fig 2) includes a MicroVax 3400 microcomputer networked to a Sun Sparcstation-based (Sun Microsystems Inc, Mountain View, CA)

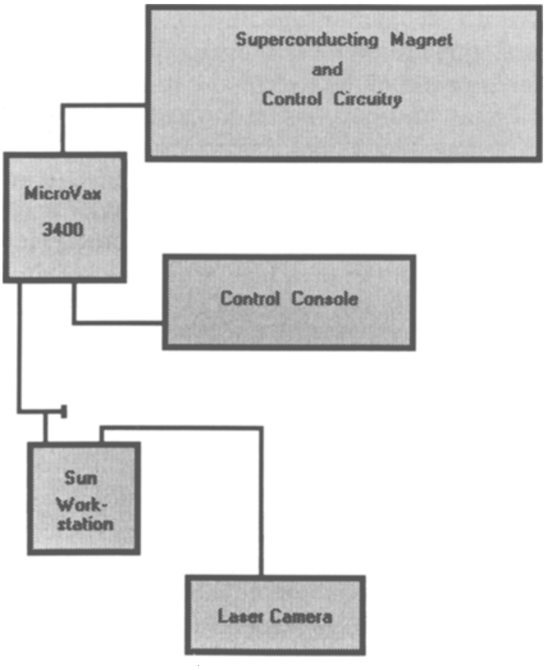


**Fig 2. Configuration of Philips T5 MR imaging system with image-processing workstation.**

image-processing workstation running Gyroview image analysis software (N.V. Philips, Eindhoven, The Netherlands). A digital optical disk interfaced with the MicroVax provides archival storage. Images can be viewed on either the console of the imager itself, or on the Sun workstation after transfer from the MicroVax or optical disk. The image file format adheres to the ACR-NEMA protocol. Pixel intensities are stored as 12-bit integers and the size of most images is 256 by 256 pixels (65,536 pixels).

For access to the ACR-NEMA files on the Sun workstation, a network link was established between it and an IBM-compatible personal computer (Fig 3). The network software selected was PCNFS (Sun Microsystems Inc) using an NI5010 board (MiLan Inc, Sunnyvale, CA) installed in the personal computer. The PC is also connected, through a separate board (NE-2000, Novell Inc, Provo, UT), to the local area network that serves the Children's Heart Center (Novell Inc). These network connections allow files to be transferred from the Sun workstation to any computer on the Children's Heart Center network.

To extract the pixel gray values from the ACR-NEMA image files on the Sun workstation, a program was written in C language on the SUNOS, or UNIX operating system. Using file format information and directory-naming conventions of the Gyroview system, this program accepts input describing the particular image file desired and reads the pixel data from the file. The program outputs a separate file containing only pixel data in 8-bit integers, stored on the Sun workstation.

The MR images obtained for our work with congenital heart defects contain pixel intensity values in a nearly constant range. This constancy of range permits the use of a single algorithm for converting from 12 to 8 bits, rather than a slightly more complex algorithm that adjusts to the range of each image separately.[9] The first conversion step is to multiply 12-bit values by 8 (a shift of three to the left). If the resulting value exceeds the maximum 12-bit value of 4,095, it is reset to 4,095. The next operation is integer division by 16 (a shift of four to the right). This discards fractional remainders so resulting integer values are from 0 to 255 (eight bits).

The resulting file contains only pixel data in the form of 8-bit integers. The values in this file, on the Sun workstation, are written into a TIFF format file (75 dpi, 3.41 × 3.41 in, uncompressed) on a user-selected PC. Conversion of formats is accomplished using a program com-

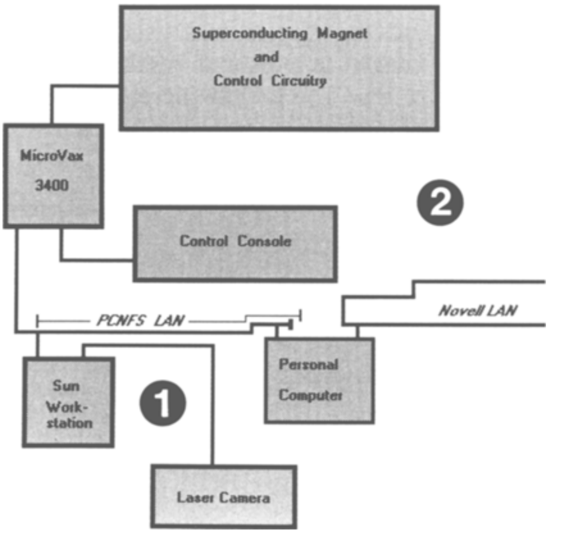


**Fig 3. Configuration of personal computer networked with (1) existing image-processing workstation, and (2) division-wide, office-computer network.**

posed of routines drawn from a commercial image-processing library (Victor Image Processing Library, Catenary Systems, St Louis, MO). The image file is now in a form compatible with the WordPerfect word-processing package (WordPerfect Corp, Orem, UT). The image can be included in a WordPerfect document and manipulated in size and position before printing on any of several printers available (Laserjet III, IIIp, on IV; Hewlett-Packard, Boston, MA). Gray levels are rendered by halftoning on paper, a process which creates shades of gray by printing black dots at varying spacings. Although halftoning does not create true gray levels, the images are of very good subjective quality. Introducing a specialized printer capable of producing true gray values would have increased the cost of the system enough to counteract the anticipated benefits.

The time required for printing can be in the range of 2 to 5 minutes for a page containing several MR images. This long time can cause problems when printing is directed over a network rather than to a printer dedicated to a single PC. Images sent over the network will occasionally have lines of extraneous characters printed over them. Because this problem has never occurred when using dedicated printers, this is the procedure most often used.

This system of image output on paper was implemented in early 1992 in the South Carolina Children's Heart Center. At first, interest was low, and the system was used only for recording images in personal research notes. Images were found to greatly increase amount and clarity of information in research notes with only a small extra effort. In the opinion of the staff, this use alone was enough to justify the development of the system.

Paper printout was next used to increase information in patient charts. A small selection of significant images could be printed in a chart, increasing significantly the information available when the chart is reviewed. Reviewing images on film or on a high-resolution monitor was necessary only for relatively detailed information. The quality of photocopies is nearly as high as that of printed originals, so information was not reduced when multiple copies needed to be distributed.

Paper printout was found to be useful in instructional materials. Both physicians and staff have stated that printed images are extremely helpful for understanding didactic materials on the physics and medical applications of MRI. The quality of photocopies allows each of many individuals to receive a well-illustrated, short text on a subject of interest.

It should be noted that TIFF images can be manipulated by image-processing packages, allowing addition of detailed annotation and diagrams to images (Fig 4). The author uses ImageStar (Microtek Inc, Torrance, CA), which runs in a Windows environment (Microsoft Corp, Redmond, WA) on an IBM-compatible PC. A recent report describes several other such packages.[10]

Paper output images have also been used for manuscripts sent for review. Illustrations can be included directly in the text with adjacent legends, greatly increasing the convenience afforded to reviewers and decreasing costs for


**Fig 4. Example of an original MR image (left) combined with a copy of the same image after processing with a PC-based image-processing program. The images have been combined in a single file.**

multiple photographic prints. In most cases, the paper-printed images clearly show all important details. Upon acceptance of a manuscript, glossy prints can be provided.

In conclusion, paper hardcopy has proved to be a useful and inexpensive additional medium for display of digital images from MR. Similar systems are planned at the Children's Heart Center for images from x-ray angiography and fluoroscopy as well as echocardiography. It is anticipated that images from several modalities can thus be displayed side by side on patients' charts, on teaching materials, and in personal research notes.

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