A Simple Image Display Application for Windows

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The purpose of this project was to develop a simple application for displaying low-to-moderate resolution digital images under the Windows operating environment. The display of scintigraphic images was of special interest, and for this reason the program was designed to show sequences of images and to account for broad ranges of pixel values. In order to function under a variety of Windows versions, the program was developed using the 16-bit Microsoft C++ compiler and targeted for Windows 3.1 enhanced. It was tested with Trionix images for nuclear medicine and Siemens for computed tomography (CT) and magnetic resonance (MR). The resulting application, called *SID*, successfully read Magnetom, Somatom, Trionix, and Interfile images of dimension 512 or less on Intel-based Windows PCs with 256 color SVGA-compatible (Super Video Graphics Adapters) video hardware. Early applications of the program included remote monitoring of image studies, resident review of teaching cases, review of research images, and preparation of educational materials. This article describes the features, operation, and potential applications of *SID*.

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KEY WORDS: digital computers, computer-assisted image analysis, radionuclide imaging

MOST PERSONAL COMPUTERS lack the hardware and software required of a comprehensive image display workstation.^{1,2} Many personal computers are, however, capable of displaying a large subset of low-to-moderate resolution diagnostic images, including those acquired in nuclear medicine, computed tomography (CT), magnetic resonance (MR), and ultrasound. For this reason, personal computers are potentially useful in the "filmless radiology" environment for education, research, collegiate conferencing, and teleradiology. Each of these activities would be assisted by inexpensive software that works on a standard operating system and that has features appropriate to the display of diagnostic images.

A public domain image display and analysis program known as NIH Image³ has been available for the Apple Macintosh (Apple Computer Inc, Cupertino, CA) for several years and more recently has been adapted for the display of nuclear medicine images (see also St. Louis University World Wide Web site at <http://www.nucmed.slu.edu>).⁴ Desired is software of a similar nature that will execute on a range of IBM-compatible (International Business Machines Corp, White Plains, NY)

personal computers (PCs) under the Microsoft Windows (Microsoft Corp, Redmond, WA) operating environment. To this end, the author developed a simple image display application called *SID* for Windows. The goals of *SID* development included the ability to display sequences of images from a single file, a reasonable flexibility in the scaling of images, the ability to rapidly adjust the color table in response to the dragging of level control bars, and encapsulation into a single executable module. This article describes the development, features, and operation of *SID*.

MATERIALS AND METHODS

SID was written for the Windows operating environment with the 16-bit version of the Microsoft C++ compiler and the Microsoft Foundation Class library. The target operating system was Windows version 3.1 enhanced, whose executables are advertised to run on any later version of the operating system, including Windows NT. The program was tested under Windows versions 3.1, 3.11 (the kernel used in Windows for Workgroups [WFWG]), 95, and NT. The algorithms used in *SID* were of the author's design. The program was tested using images acquired on Trionix (Trionix Research Laboratory, Twinsburg, OH) systems for nuclear medicine and Siemens (Siemens Corp, New York, NY) systems for MR and CT. The program also was tested for images archived under Interfile.

RESULTS

Description of Features and Commands

The primary design goal in the development of *SID* was to display a sequence of two-dimensional images stored contiguously within a single file. To achieve this goal, both single and multiple image display modes were implemented. In single image display, commands are provided for selecting a given image within a file, stepping through a sequence of images, or seeking the top or bottom of the image file. The number of the image currently being displayed is shown in the title bar of the image window, directly after the file title.

In multiple display mode, the image number

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0897-1889/97/1003-0004\$3.00/0*

represents an index that facilitates selecting or stepping through *screens* of images. In keeping with the intended simplicity of design and the generation of a single executable module, SID will simultaneously display as many images as can fit in the maximized client area of the main window. The number of images in a given screen will depend on the resolution of the images (row and column size) and the screen resolution. The screen resolution is, in turn, determined by the display mode of the PC video hardware as specified in the Windows Setup program. For example, SID will simultaneously display 12 images of dimension 256 (row size in pixels) $\times$ 128 (columns) on a system set in 800 $\times$ 600 display mode.

SID assumes that all of the images within a given file have identical resolution. Row and column dimensions of the images independently can vary from 64 to 512 in multiples of 2. In multiple image display mode, the image index number typically refers to the image in the upper left corner of the screen. If the index image falls within the last screen of images, SID will fill the screen so that the lower right corner contains the last image in the file. In a given screen, images are row-ordered from top to bottom.

SID provides a command to magnify images. Each execution of the "magnify" command will enlarge both the row and column dimensions of the images by a factor of two, whereas each execution of the "minify" command will reduce the dimensions of the enlarged images by the same factor. The number of magnified images displayed in a given screen will be adjusted as if the original images were correspondingly larger. SID provides a toggle command that when set will cause any magnified images to be interpolated.

SID permits the main window to be adjusted to any size. Horizontal and vertical scroll bars are provided to reveal portions of the client area (screen of images) that are hidden when the main window is less than maximal. Currently, SID will read only one file of images at a time. The display of multiple sets of images in multiple files can be achieved by invoking the program multiple times (invoking multiple instances of the application).

SID requires that the user specify the characteristics of the images before opening the file and reading the images for display. A command labeled "Image Type" appears on the "File" menu just above the "File Open" command. "Image Type"

opens a dialogue window in which the user specifies the dimensions of the images, the pixel size, the byte order, and the size of any header that may be present. The header is descriptive information located in the front of the file before the start of the images. The size of the header can be specified in bytes or K-bytes.

The information requested in the "Image Type" dialogue should be obtained from the vendor of the machine that performed the image acquisition. Frequently the image file characteristics can be discovered by trial-and-error. If the image file to be read is in the Interfile format, the Interfile header itself will provide the necessary information to complete the "Image Type" dialogue. The Interfile header will be in ASCII format and can be reviewed simply by reading the file with a text editor.

For pixel size, SID supports byte (8-bit) or word (16-bit) unsigned integers. For byte order, SID supports big-Endian as well as little-Endian formats. Endian refers to the manner in which multi-byte sequences are stored in memory and on disk. If an image was acquired on a system that uses the UNIX operating system, likely the ordering will be big-Endian. If the image was acquired on a PC, likely it will be little-Endian. In SID, designating "big-Endian" causes every other byte in the image to be swapped, independent of whether the pixel size is word or byte.

Currently, SID will properly display images only if their pixels are stored sequentially in top-to-bottom row order. This top-to-bottom row-ordered format is the one used by Interfile and also is used by several commercial systems. In addition, SID expects that multiple images within the same file appear contiguously, so that the first pixel of the next image falls immediately after the last pixel of the current image. Again, this feature is common to image files used by commercial vendors and is expected with Interfile. Finally, SID assumes that an image file ends with images; that is, the image file has no epilogue. This latter consideration is merely theoretical because the author has yet to encounter image files with epilogues.

One of the design goals of SID was to optimize the display of images having wide-variations in pixel values. Several features were implemented in an attempt to meet this goal under the constraints of limited hardware and simplicity of design. First, SID can load from disk a translation table (also known as a color table, look-up table, or color

map). The translation table is used to convert pixel values into display colors or shades of gray. Three translation tables currently are provided. SID translation tables are coded in binary as 256 bytes of red intensities, followed by 256 bytes of blue intensities, followed by 256 bytes of green intensities. Once the colors are loaded, SID provides a command to invert the entire table.

Second, SID provides two pop-up dialogue windows for adjustment of the color table. The "Window Controls" dialogue provides slider bars for adjusting lower (LL) and upper (UL) window levels; the "Brightness Controls" dialogue provides slider bars for adjusting image brightness (UC) and contrast (LC). SID allows the slider bars to be dragged and will modify the color table "on the fly." This animation of the color table permits the user to rapidly view a broad range of pixel intensities and was an important design goal of SID. A color bar also is provided as a pop-up window to display the adjusted color table.

Finally, SID provides flexible means for adjusting the images to determine the pixel value of maximum intensity. One of three methods can be selected. First, each image can be scaled independently to its maximum pixel value. Second, each image can be scaled to the maximum pixel value of the entire set of images within the file. Third, all of the images can be scaled to a fixed value. This fixed value is specified in bits; it is the maximum value that can be stored in the given number of bits, or $2^{\text{bits}} - 1$. When scaling to a fixed value, pixels greater than or equal to this value are displayed at maximum "intensity" (the color or gray shade at the top of the color table); pixels below this fixed value are distributed across the "intensity" range. This latter method of scaling is valuable for visualizing low-value pixels in images having high maximum pixel values. Radioiodine surveys for recurrent thyroid carcinoma are examples of images for which this method is useful.

SID has a command for saving the index image as a PC Paintbrush (ZSoft Corporation, Marietta, GA) PCX file. The PCX format is widely recognized by commercial graphics display software and image conversion software. For example, an image can be saved to PCX and then imported as a picture into Microsoft PowerPoint. Within PowerPoint, the image can be reduced, enlarged, labeled, or annotated; it can be used to accompany a graph or formed into a collage of images. When SID exports

an image to PCX, it saves the image according to the adjustments made by SID to its display. These adjustments would include any magnification, interpolation, and scaling. It would also include the effect of the current color table on the image, including the window level and brightness control settings and the state of inversion.

Testing and Implementation

SID was tested exclusively on PCs with Intel (Intel Corp, Santa Clara, CA) processors and super video graphics adapters (SVGA). SID functioned without anomalies under Windows 3.1 (enhanced mode), WFWG, Windows 95, and Windows NT with one exception: NT would not display the color bar on the current version of SID. Not surprisingly, monitor quality (dot pitch, convergence, and band width) had a noticeable affect on image quality, whereas processor and bus speed had a noticeable effect on image display rate. PCs having externally cached Intel iAPX 32-bit DX processors were judged to be adequate hosts. In addition, animation of the color table was judged to be adequate with even 16-bit ISA (industry standard architecture) video cards, provided that the video BIOS was shadowed in (loaded into) RAM. PCs with Intel 486 DX2 or DX4 processors and local bus video or with Intel Pentium/Pentium Pro processors and PCI bus video were more ideal hosts. When multiple instances of SID were invoked, the number that could be run simultaneously depended on the amount of available memory as well as the percentage of free Windows system resources. Allowing just over a megabyte of memory for each instance of SID proved to be a good rule of thumb.

Using the "Image Type" dialogue, SID was capable of displaying Trionix BIAD/TRIAD, Siemens Magnetom, and Siemens Somatom Plus planar image files whenever either dimension of the image matrix was a multiple of 2 between 64 and 512. SID also was capable of displaying unsigned byte or word Interfile images whose dimensions similarly were less than or equal to 512. As an example, the following "Image Type" dialogue settings were used to display Magnetom images: row size 256 pixels, column size 256, word pixel size, big-Endian byte order, and 8K header (offset to image data).

SID applications to date have included the monitoring of clinical image studies, the review of processed and unprocessed digital images acquired

during the course of research, the review of teaching cases with residents, and the creation of slides. The monitoring of image studies has been made possible by a network file system (NFS) that allows SID to open an image file on the remote acquisition system as if the file were stored on the local PC (network drive). For systems on the large area network that do not have PC-compatible NFS support, FTP (file transfer protocol) has been used for image file transfer. Whenever research and teaching files have been archived under Microsoft data operating system (MS-DOS), typically they have been renamed, compressed using static Huffman encoding, and annotated using a separate text file, as appropriate.

DISCUSSION

The display of diagnostic images on PCs can take several approaches. One method is to convert a given vendor's images into one of several standard raster formats, such as GIF, JPEG, TIFF, BMP, or PCX. The image file then can be read by one of several inexpensive programs available for their display. One limitation to this approach is that the controls provided with these programs are more suited to the adjustment of color photographic images than to the adjustment of medical images. Another limitation is the time and expertise needed to write, or the expense to obtain, the conversion software. Some of these formats are quite complex in their implementation, whereas the simpler formats tend to encapsulate only a single image rather than an image sequence. Depending on the raster format and the original image characteristics, the conversion process itself can result in the loss of information content. Such losses may be acceptable for the purposes of illustration and education and might even be necessary for long distance transmission. A means for viewing the original pixel data, however, is most desirable.

Another approach depends on a hardware vendor providing a method for exporting its diagnostic images into a standard industry format such as Interfile or American College of Radiology-National Electrical Manufacturers Association (ACR/NEMA)/Digital Imaging and Communications in Medicine (DICOM). One then obtains a program such as NIH Image (public domain for the MacIntosh), or plug-in such as ImportACCESS (DesAcc, Chicago, IL) (commercial product for the

MacIntosh), that either will display the images or convert them into a standard raster format.

Since the inception of SID, NIH Image actually has been ported to the PC by Scion Corp (Frederick, MA). Scion's ImagePC Beta 1 version can be downloaded freely from the Internet, and it has some image editing and processing commands, such as rotate and flip, filters, edge finding, and scalar arithmetic. ImagePC *requires* Windows 95 or Windows NT. Also, even in its Alpha 9 version it remains to be determined whether ImagePC can read DICOM files or can import Interfile images in which the pixel size is word length (16-bits).

In addition to ImagePC, OSIRIS recently has been ported to Windows. It is a general image manipulation program originally developed for UNIX.⁵ OSIRIS reads a file format called PAPYRUS that is based on the DICOM standard. The OSIRIS PC version is targeted for Windows 95 but apparently can be used on Windows 3.11 with some restrictions. The OSIRIS authors freely distribute the program for academic, noncommercial use.

As described here and provided it is not resold, SID is distributed freely and not restricted to any particular operational environment. SID should run on any version of Windows from 3.1 enhanced through NT. SID can import images from files containing contiguous byte or word-length images and should be capable of reading a large subset of Interfile data sets.

SID, by definition, is a simple program whose primary function is to display screens of images derived from single files. Expression of the entire dynamic range of an image and precise operator adjustment of the display were concerns in SID design. SID attempts faithful representation of pixel values under constraints of operating system architecture, variable processor speed, and simplistic video hardware. For these reasons, SID does not stretch or dither images or otherwise compensate for the aspect ratios of various PC screen resolutions. In addition, SID requires that Windows be placed in a 256 color mode and that the video hardware supports a color palette in this mode. SVGA and their compatibles provide such display attributes. The SVGA specification has become a standard in the industry and most PC users work in an 256 color SVGA environment for reasons of speed and compatibility.

SID has potential applications in teaching, research, and practice. SID allows students and

residents to manipulate raw image files from teaching cases and review all facets of an image set. Because SID can be freely distributed and many students own PCs, "off-line" self-study of medical images becomes practical. SID also can be used to export individual images to other software for the creation of formal illustrations or informal displays targeted for colleagues, referring physicians, or patients. When low-to-moderate resolution images are involved, SID has the potential for use in teleradiology or even teleconferencing. Once the practitioner has adequately documented the reliability of such an application for medical purposes, formal remote image interpretation becomes practi-

cable. Finally, SID can be used to quickly review the results of separate nongraphic programs used for image processing, especially during the preliminary research. SID can be downloaded from the World Wide Web by using the file directory at <http://frog.image.uky.edu> or can be obtained directly from the author at the contact address.

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance of Tony Bengé and David Brown at the Center for Biomedical Engineering for the testing of SID, as well as Wenner Gren Research Laboratory for its provision of the downloadable site.

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