Web-Based Viewing of Picture Archiving and Communications Systems Images—Part I: Optimal Personal Computer Configuration

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Now that picture archiving and communications systems (PACS) has matured, our challenge is to make the images available to the referring physician and, in a teaching institution, to make these images available for conferences and rounding. One solution is the distribution of the images using web-based technology. We investigated a web-based add-on to our PACS to determine the characteristics of the personal computer that will make this technology useful and affordable. We found that images can be viewed easily through a web-based system. We found that the optimal system to view these images at a reasonable speed and a reasonable cost is on with a medium-range processor (200 to 300 MHz) and a large amount of inexpensive RAM, at least 64 Mb.

ELECTRONIC RADIOLOGY is maturing rapidly. Picture archiving and communications systems (PACS) are installed in many institutions, and the technology, reliability, availability, and affordability have improved over the last few years. The field has matured so that it is a practical and desirable method of delivering radiologic services. As departments make their way toward filmless environments, new challenges arise. The images, though easily accessible in the Radiology Department, are unavailable at sites traditionally using film, such as conferences, physician rounds, physicians' offices, and preparation of publications. Several solutions are available, including limiting access to the images, printing film, widespread use of expensive workstations, and web technology.

Web distribution is an attractive solution as it utilizes standard hardware available in many locations in a modern hospital environment. We are investigating the utility of this technology. The purpose of this presentation is to evaluate the characteristics of personal computer (PC) that will make this technology useful and affordable. The primary factors considered are processor speed and RAM.

MATERIALS AND METHODS

Our institution is a tertiary medical center with 580 staffed beds and several outpatient clinics. We perform 225,000 examinations per year. We are phasing in PACS with the intent of becoming filmless. Currently, we are using a commercially available PACS (AGFA, Inc, Ridgefield Park, NJ) with a redundant array of inexpensive disks (RAID) of 256 GB on an asynchronous transfer mode (ATM) network, one gateway, eight diagnostic review stations (Sun Microsystems Inc, Palo Alto, CA) in Radiology, two diagnostic review stations in the Emergency Department, as well as 10 PCs with individual display software, CS-500 (AGFA, Inc). An Ultra Enterprise II Sun Sparc web server with a 50-GB RAID has been added. As images are sent to the PACS, they are mirrored to the web server using lossless wavelet compression of 3 to 1.

The software to display the images on the user PC is a standard web browser (Netscape 4.05) using a JavaScript developed by Mitra Imaging (Hartland, WI). The software allows examination listing using selection criteria (Fig 1). The display can be in various formats from one to 16 images or thumbnail display of the entire exam. Twelve-bit data are transmitted and displayed, allowing full windowing (Fig 2). Images can be obtained from the server in both uncompressed and compressed format.

Testing was performed on four standard PCs running Windows 95 (Microsoft Corp, Redmond, WA). The system configurations that were evaluated included 32, 64, 96, and 128 MB of 60 ns extended data output (EDO) RAM on a 200-MHz Pentium processor with 66 MHz bus, 128 MB on 266 MHz Pentium II laptop, and 64, 128, 196, and 256 MB 8 to 10 ns SDRAM on the 300 and 400 MHz Pentium II (Intel Corp, Santa Clara, CA). The 300 and 400 MHz processors used a 66 MHz bus and a 100 MHz bus, respectively. These systems are connected to the hospital ATM (FORE) backbone by unswitched ethernet at 10 Mb per second or less.

At a time when the network activity is low and relatively stable (early evening), images from five computed tomographs (CTs), two magnetic resonances (MRs), and five plain films were accessed. The same images were accessed in each configuration. CTs and MRs were viewed in 16-on-one format and plain films were viewed as one-on-one format. Length of time from the moment the display button was pressed to when the complete image/series was displayed was recorded as the time-to-display (TTD). The plain film images were 8 to 10 MB, the CTs averaged 0.5 MB per image or 8 MB per 16, and the MRs averaged 0.13 MB per image or 2 MB per 16.

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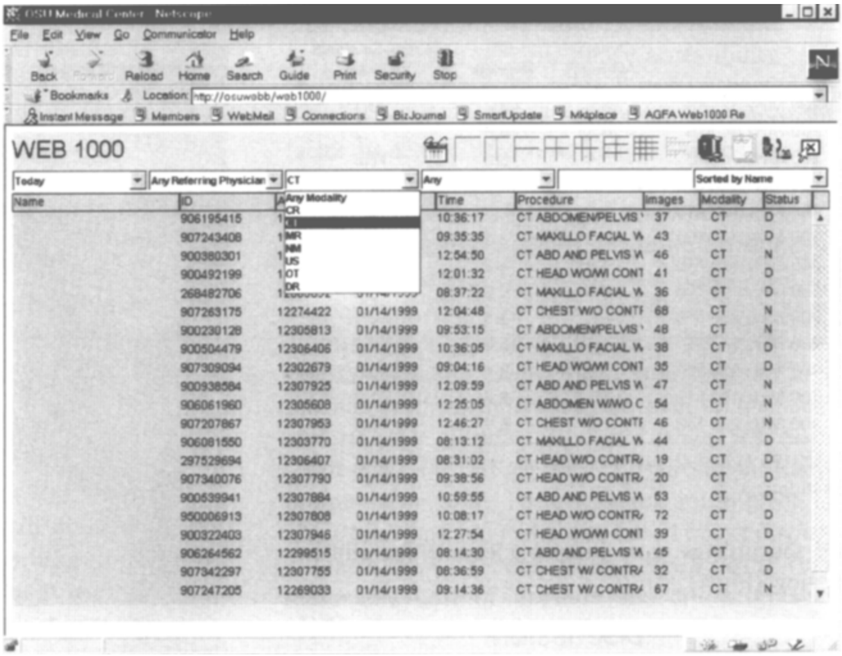

Fig 1. Netscape 4.05 running Web 1000 JavaScript. This screen shows the selection capabilities of the patient list screen. Selection criteria and list mode is similar to standard PACS.

RESULTS

The TTDs ranged from 4.5 seconds to 71.1 seconds, with a mean of 12.4 seconds and a median of 9.2 seconds. The averages for each configuration are listed in Table 1. As seen in Fig 3, there is a trend for shorter TTDs as the processor speed increases. The TTD is roughly inversely proportional to the speed of the processor. There is also a dramatic difference in the TTD by increasing the RAM from 32 to 64 MB. The TTD decreases by 59%. Above 64 MB, there is a smaller decrease on the average of 22%. The TTDs of the cross-sectional images compared with the plain film images was not significantly different. Images were evaluated for diagnostic quality by a radiologist. A comprehensive evaluation was not performed, but

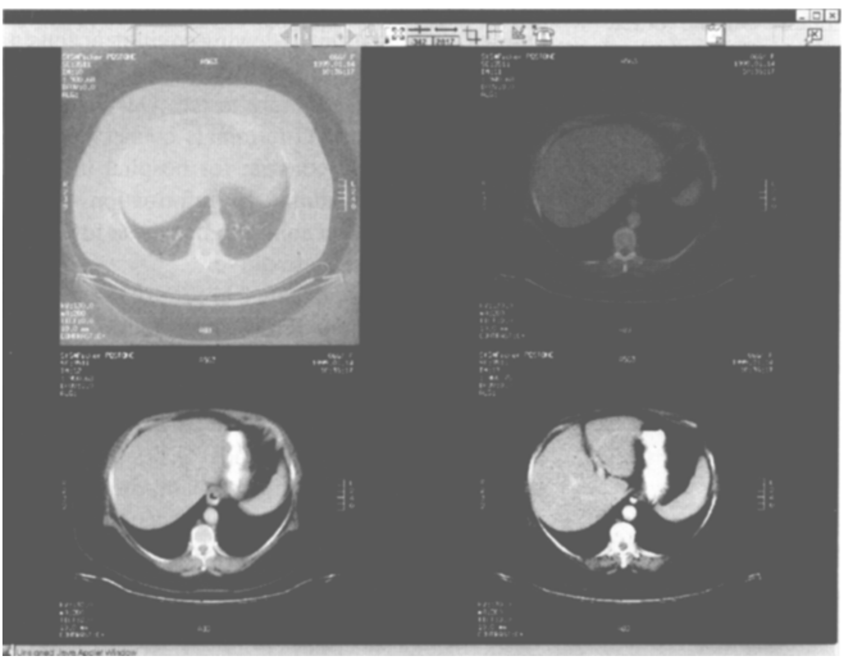

Fig 2. Image display screen of Web 1000 showing the windowing capabilities. Lung, bone, soft tissue, and liver windows are displayed.

Table 1. Average TTD for the Different Configurations Tested

	Overall Average	CR Average	Cross-Sectional Average
200 MHz 32 MB	38.9	49.2	30.1
200 MHz 64 MB	16.1	14.9	17.2
200 MHz 96 MB	16.4	15.0	17.6
200 MHz 128 MB	12.5	11.5	13.2
266 MHz 128 MB	9.5	8.3	10.6
300 MHz 64 MB	11.3	12.1	10.6
300 MHz 128 MB	8.8	8.3	9.3
300 MHz 192 MB	8.4	8.3	8.5
300 MHz 256 MB	8.8	8.4	9.1
400 MHz 64 MB	12.9	15.0	11.2
400 MHz 128 MB	7.3	6.9	7.6
400 MHz 192 MB	7.3	6.8	7.7
400 MHz 256 MB	7.1	6.7	7.4

NOTE. Averages are arranged as overall, CR, and cross-sectional.

all the images were judged adequate for clinical review (Fig 4).

DISCUSSION

Our institution has been involved in a partial PACS solution for approximately 18 months. During the time of evaluation, it has become evident that PACS is a viable means of storing and interpreting images. We have therefore embarked on the road to become filmless. Along this path, we foresee several obstacles, including the availability of images to the referring clinician, residents, students, and other personnel. Distribution of images throughout the hospital on high-performance display stations is cost-prohibited. On the other hand, we feel that it is important for the physician and student to have access to the images. Distributing the images by a web server seems to be a cost-effective method to allow access to the images. We have shown in a previous study that review images on a PC utilizing medium-level software (CS-500) was accurate and sufficient for viewing by the referring physician.[1]

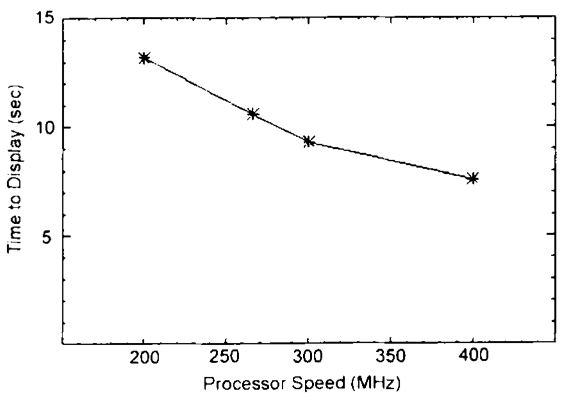

Fig 3. Plot of time-to-display versus the processor speed. The plot is close to linear, but levels off slightly.

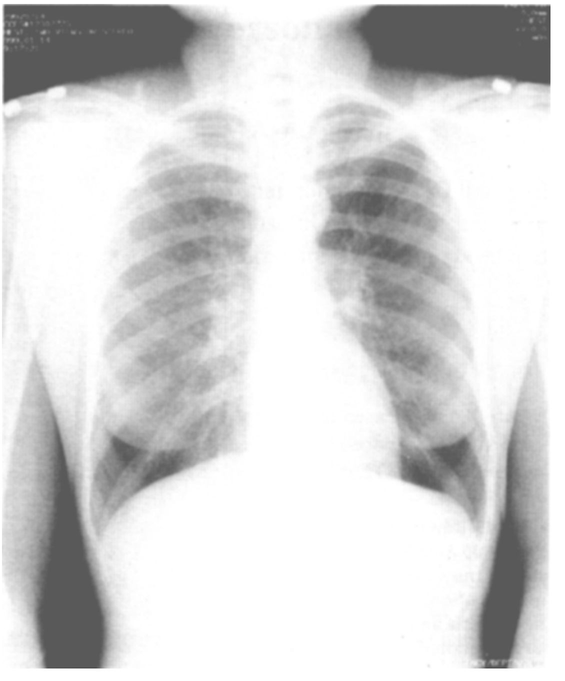

Fig 4. Posteroanterior chest image showing the quality of the display. Fine vascular detail can be seen. These images can also be magnified to full resolution.

The task of this project was to evaluate the optimal configuration of viewing equipment considering cost and speed of display. Several configurations of standard PCs were tested. Our institution has many standard PC terminals connected to an ATM backbone by ethernet for hospital information systems and radiology information system already in place. The ability to use these for image displays is extremely attractive.

Several interesting, though expected, results were found. At a constant RAM size, the system performed as expected with a display speed relative to the processor speed. The 400 MHz units (averaging 8.7 seconds TTD) were twice as fast as the 200 MHz (averaging 51.1 seconds TTD). This is not quite a linear relationship, probably because network transmission time contributes a portion of the TTD and at some higher speed there may be no change in the TTD relative to the processor speed.

The most significant factor identified in the TTD is the amount of RAM. There was a large decrease in the TTD when increasing the RAM from 32 (averaging 38.9 seconds TTD) to 64 MB (averaging 16.1 seconds TTD) on the 200 MHz machine. This represents a 59% decrease in the TTD. Beyond this RAM size, there was no significant decrease in the 200 MHz machine. On the faster processors the average decrease in TTD was 20% from 64 to 128 MB and 1.4% from 128 to 256 MB. Again the improvement in speed approaches 0 as the RAM increases. It is highly likely that this is because the system software and the browser software occupy a larger percentage of the available RAM at 32 MB and above this level disk caching is reduced.

Several factors can effect the TTD. Only RAM and processor speed were tested in this study. Other factors include connections, network activity, compression, and others. Connection at our institution is both unswitched and switched ethernet. The machines that were used all used unswitched ethernet connections. Network activity is the most difficult to assess or keep constant. The measurements were made in late afternoon and early evening when the activity on the network was relatively stable and relatively low. Some of the variance of the data can be attributed to the network traffic. A moderate sized sample and averaging of the data helped to nullify this effect. Compression of images was also studied and will be dealt with in Part II.

CONCLUSION

It is important to make image accessibility easy and reasonably rapid for PACS to be accepted by the rest of the hospital. Costs are an important factor in determining how images will be distributed. We found that the speed of the image display with web technology improved with processor speed and increasing RAM of the PC. A dramatic increase in display speed can be accomplished by increasing RAM from 32 to 64 MB. Though there is increase in speed with increasing processor speed, we do not believe decreasing from 16 to 9 seconds justifies the costs. We believe the most cost-effective system is a mid-range processor (currently 200 MHz) with a mid range RAM (currently 64 MB). These systems are in place in many locations and make web-based image display a viable tool to compliment PACS at a very reasonable cost of upgrade and are acceptable configurations for display. We also believe that the optimum system is high range (currently 400 MHz) with mid to high range of RAM (currently 128 MB). These will certainly change in a short period of time. If you are buying new equipment, you should opt for the optimum.

REFERENCE

1. Spigos DG, Tzalonikou MT, Bennett WF, et al: Accuracy of digital imaging interpretation on 2K × 2K and 1K × 1K workstations in the emergency department. Radiology 209 (P):328, 1998 (abstr)