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FACTORS AFFECTING PERFORMANCE OF PACS

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INDEXING WORDS

PACS; color PACS; efficiency of PACS; personal computer

SYNOPSIS

We experimentally constructed a personal-computer-based Picture Archiving and Communication System (PACS) for color images of dermatology clinics. This system should especially satisfy such a demand as to be able to retrieve an image within a few seconds from the database residing in a remote server. Our two objectives in the experiment were: To examine how much time was consumed in each part of PACS while it does a series of jobs, from the requesting of an image to its display on the screen of the workstation of the user. The other objective was to see if a personal-computer-based PACS could satisfy our criteria. Total retrieving time, data reading time, data transporting time and image displaying time were measured. Total retrieving time can be divided into three procedures: Data reading time, data transporting time, image displaying time. Data reading time was about 0.6 second for reading an image with the size of 1 mega bytes (MB). Data reading time and the size of data were linearly correlated. Data transporting time was about 11 seconds for transporting an image with the size of 1 MB through EtherTalk, and 66 seconds through LocalTalk. Data transporting time and the size of the data were also

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linearly correlated. Data reading time and data transporting time was able to be reduced largely by compression technique. However, smaller data give other important effects to the network system besides reducing the time of data reading, data transporting and data displaying. Most Local Area using image Network (LAN) systems, such as EtherTalk, adopt Carrier Sense Multiple Access with Collision Detection (CSMA/CD) for the way of accessing to other computers. In CSMA/CD, transporting performance suddenly declines if the congestion of signals in a network gets beyond a critical level. This situation fatally impairs the performance of a network. We concluded that data compression plays an important role to improve the performances of PACS, especially those of a server and the network system. A personal-computer-based PACS with EtherTalk and an image compression/decompression hardware, e.g., CL550A chip, satisfies our criteria.

INTRODUCTION

Many radiological images such as plain X-ray, computed tomography (CT), magnetic resonance image (MRI), angiogram and so forth are taken in hospitals. To utilize these image data more efficiently, PACS is being introduced. In PACS, high performance speed, images of high quality and an easy-to-use user interface are demanded. We constructed experimentally a personal-computer-based PACS for color images of dermatology clinics. Our two objectives in the experiment are: To examine how much time was consumed in each part of PACS while it does a series of jobs, from the requesting of an image to its display on the screen of the workstation of the user. The other objective was to see if a personal-computer-based PACS could satisfy our criteria.

This system should satisfy the following criteria: (1) An image is retrievable within a few seconds from the database residing in a remote server, (2) A server and several image workstations are connected by LAN system; (3) The quality of image is good enough for clinical use; (4) The image workstation has an easy-to-use user interface; (5) The initial installment cost is low. Among the above mentioned criteria, we chose to examine the item (1) for our PACS.

Comparing the quality of images on film and those on screen of an image workstation is very difficult because the film does not have a distinct pixel as in the screen. The property of the photosensitizer of films, however, seems to give it the value equivalent to the pixel of about 10 μm X 10 μm[4]. According to this, a 35 mm slide film comprises about 8.1 X 10^6 pixels. Images that are taken by a NTSC-type TV camera have 3.0 X 10^5 pixels. The difference between the resolution of films and that of the video images is very large. Moreover, it is very difficult to improve the quality of the images displayed on the screen to the level of the film. Therefore, from our point of view, objects that need to be taken at higher resolution level can only be taken with larger magnification. Image compression loses some parts of the original image. Usually, the lost part is not so important as to affect the decompressed image and the users can not detect the difference between the original image and the decompressed image up to a certain compression level. We approved that image compressed by Joint Photographic Expert Group (JPEG) up to the level of 1:10 did not ruin the quality of the original image. Considering the above, we have decided not to discuss the quality of images in this paper.

MATERIALS AND METHODS

Fig. 1 shows the block diagram of our personal-computer-based PACS. A CCD-TV camera (SONY's DXC-750) was used to take a photograph of patients and the appearance of skin diseases. Computers need an interface that digitizes the video signal sent from a TV camera because the output signal of most TV cameras are analogue. We used RasterOps' 24XLTV for the interface. It has a sampling rate high enough to display images as large as 640X480 pixels. We chose Macintosh IIfx and Quadra 900 (the best grade of Macintosh series) as image workstations. The easy-to-use user interface of Macintosh IIfx and Quadra 900 satisfies one of our criteria[1). IIfx has 68030 CPU with a 40 MHz clock and 32 MB of main memory as maximum. Quadra 900 has 68040 CPU with a 25 MHz clock and the maximum main memory of 64 MB. Macintosh family computer has NuBus system for an interior bus system. NuBus acts with 10 MHz clock in Macintosh IIfx and with 20 MHz in Quadra 900. IIfx has the power of 8 mega instructions per second (MIPS). Quadra 900 is twice as fast as IIfx. Quadra 900 was chosen also as the server. For our image compression/decompression system, JPEG 9R9 of QuickTime and JPEG 8R2 of C-Cube's CL550A chip were used. For mass storage, a hard disk system mounted in the sever was used. For LAN system, LocalTalk and EtherTalk were used. The transporting rate of LocalTalk is 240 kilo bits per second (Kbps) and that of EtherTalk is 10 mega bits per second (Mbps).

We used HyperCard ver.2.1 for the front end software of our PACS[2)3)]. Other programs, i.e., an image database system, a server and client communication program, a control program for 24XLTV board, a Karte system, were originally made in 'C' language[5)] and were attached to HyperCard as xcmd[6)].

PACS consists of these three main components: a server, a network system and image workstations. It is very important on planning PACS to estimate how the total performance was affected by improvements of each component. Total retrieving time can be divided into three procedures: Data reading time; Data transporting time; Image displaying time. Total retrieving time, data reading time, data transporting time and image displaying time were measured.

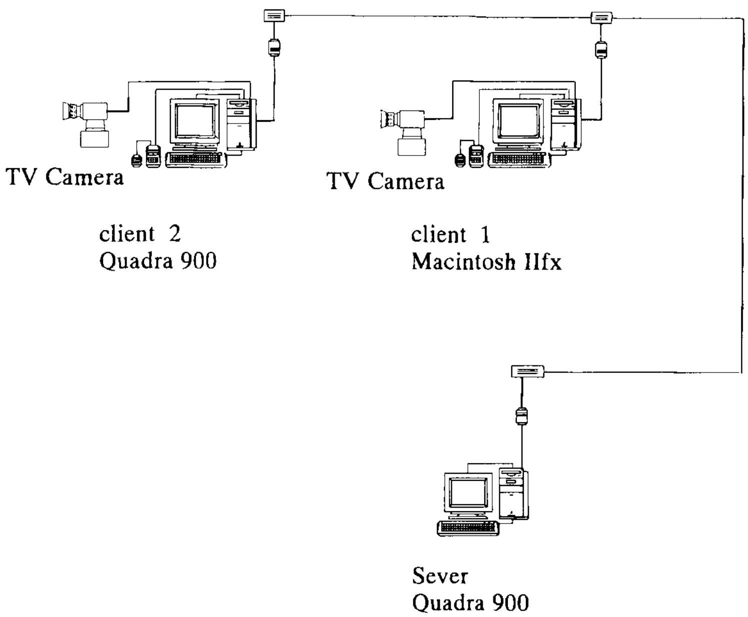

Fig. 1. Block diagram of a personal-computer-based PACS for dermatology clinics.

Data reading time (R) is related to the performance of a server, and is the time needed for an image in the image database on a hard disk to be read out to the memory of the server. R was measured for several sizes of images.

Data transporting time (T) is related to the performance of a network system, and means the time needed for an image on the memory of the server to be transported to the memory of an image workstation through LAN system. LocalTalk and EtherTalk were compared.

Image displaying time (D) is related to the performance of image workstations, and is the time needed for an image on the memory to be displayed on the screen of a workstation. This was measured for raw (noncompressed) image, image compressed by QuickTime, and image compressed by CL550A. The compression level was about 1:10. Macintosh IIfx and Quadra were also compared.

Total retrieving time shows the time that is taken for the users to request an image and to have it displayed on the screen of the workstation. Total retrieving time was measured for the same three images as in D. The compression level was about 1:10. Other conditions were: The disk system was the one that was mounted in the server (Quadra 900); LAN was EtherTalk.

RESULTS AND DISCUSSION

Fig. 2 shows data reading time (R). This result shows that R and the size of the data are linearly correlated. R is about 0.6 second for reading an image data with the size of 1 MB. Fig. 3 shows data transporting time (T). This result shows that T and the size of data are linearly correlated. T is about 11 seconds for an image data with the size of 1 MB through EtherTalk, and 66 seconds through LocalTalk. EtherTalk is 41 times faster than LocalTalk in calculation, but as Fig. 3 shows, EtherTalk is in fact only 6 times faster than LocalTalk. This means that the transporting rate does not relate to T linearly. Fig. 2 and Fig. 3 show that R and T can be reduced largely by using the image compression technique because the image compression reduces the size of data in proportion to the compression level. The image was already compressed in an image workstation when it was taken. The process of compression/decompression does not affect R and T at all. That is, R+T is linearly correlated to the compression level. Fig. 4 shows image displaying time (D). This result shows that D and the size of data are linearly correlated. Fig. 4 shows, however, that the D with data compression by using CL550A at level 1:10 is half the D without data compression. This means that D is not linearly correlated to the compression level because D includes the time needed for the process of decompression besides the time actually needed to display an image. Fig. 5 shows that the total time needed to retrieve an image with the size of 1 MB is: 18 seconds without the image compression, 13 seconds decompressed by QuickTime, and 3 seconds decompressed by CL550A chip. In the Table I, the time needed for data reading and data transporting was compared with EtherTalk and with LocalTalk, and between raw images and images compressed by QuickTime and CL550A. Table II shows the time needed for image displaying for raw image, image compressed by QuickTime and image compressed by CL550A.

Our result shows that data compression plays an important role to improve the performance of PACS. Data compression makes the size of image smaller and reduces time consumption all over the system, especially in the server and in the network system. However, smaller data give other important effects to the network system besides reducing the time of data reading, data transporting and data displaying. Our PACS has only two image workstations and so we did not need to consider the situation where requests from image workstations were congested. Most LAN systems, such as EtherTalk, adopt CSMA/CD for the way of accessing to other computers. In CSMA/CD, transporting performance suddenly declines if the congestion of signals in a network gets beyond a critical level. This situation fatally impairs the performance of the network.

Table I. Time needed Reading and Transporting (R+T) for 1 MB image on Quadra 900.

Compression	EtherTalk (seconds)	LocalTalk (seconds)
none	11.7	68.7
1:10 compression	1.6	8.0

The time needed for data reading and data transporting was compared with EtherTalk and with LocalTalk, and between raw images and images compressed by QuickTime and CL550A.

Table II. Time needed Displaying (D) for 1 MB image on Quadra 900.

Compression	Display Time (seconds)
none	3.5
QuickTime	5.3
CL550A	1.7

The time needed for image displaying for raw image, image compressed by QuickTime and image compressed by CL550A.

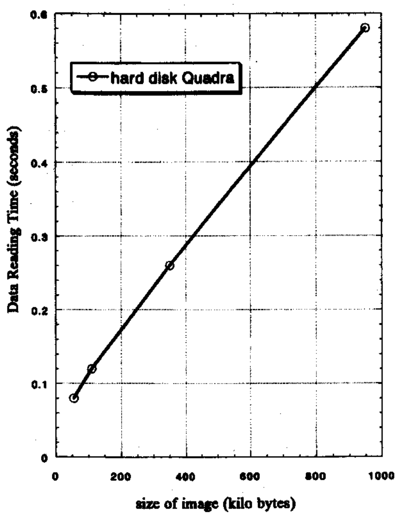

Fig. 2. Data Reading Time shows the time needed for an image in the image database on a hard disk mounted in a server to be read out to the memory of the server.

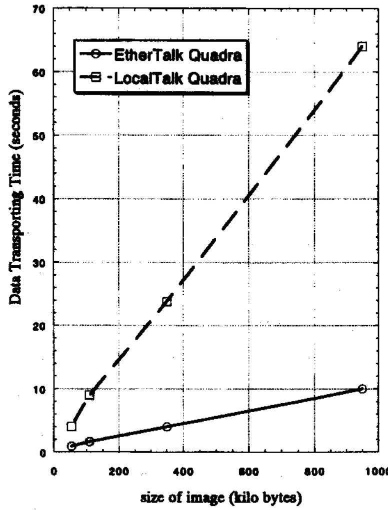

Fig. 3. Data Transporting Time shows the time needed for an image on the memory of the server to be transported to the memory of an image workstation through LAN system.

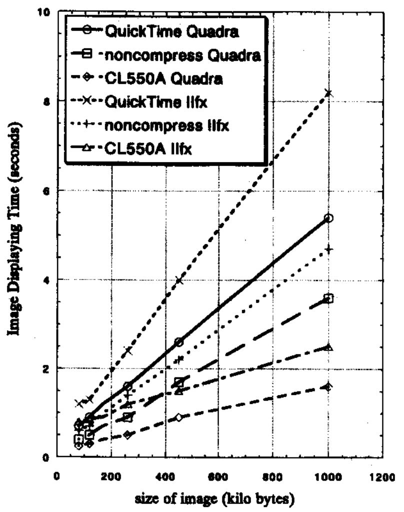

Fig. 4. Image Displaying Time shows the time needed for an image on the memory of an image workstation to be displayed on the screen of the workstation.

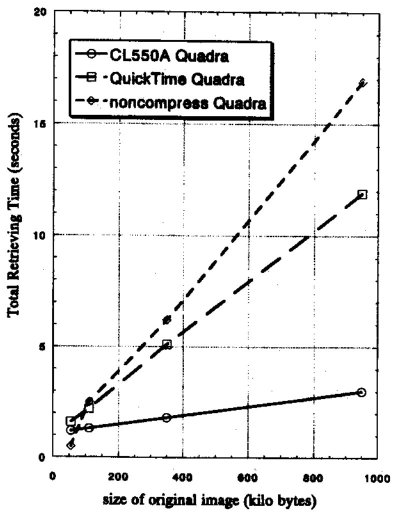

Fig. 5. Total Retrieving Time shows the time that is taken for the users to request an image and to have it displayed on the screen of the image workstation.

EtherTalk is 41 times faster than LocalTalk in calculation, but as Fig. 4 shows, EtherTalk is in fact only 6 times faster than LocalTalk. This shows that the simple use of high speed network system, such as Fast-Ethernet of transporting rate 100 Mbps, does not mean that the transporting time will dramatically improve.

Improving of image displaying time does not have any effect on the network performance at all. But, image displaying time takes a half part of the total retrieval time in our system. From the user's point of view, reducing the image displaying time gives a considerable improvement in the performance of the PACS.

A personal-computer-based PACS with EtherTalk and an image compression/ decompression hardware, e.g., CL550A chip, satisfied our criteria. It took only 1.6 seconds for our server and network system to send data with the size of 100 kilo bytes (KB), equal to an image with the original size of 1 MB compressed to one tenth. That is, our server and network system can serve 100 KB per 1.6 seconds to an image workstation, or 1 MB per 16 seconds. This shows that image compression is necessary for a personal-computer-based PACS.

This system did not cost more than 4 million yen in 1992; not including the cost of software and that of the TV camera.

Our PACS can be used not only for color images but also for monochrome images such as X-ray films, if we adopt a compression chip for monochrome images. Large-scaled PACS such as the one used in Kobe University Hospital can be constructed by installing our small-scaled systems in every clinic in the hospital and by connecting each small-scaled PACS using the internet connection technique.

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