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〔Original Paper〕

Diagnostic Image Communication System in an Era of Network Communication —Advanced PACS Based on the Intranet Technology and DICOM Image Format—

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SUMMARY

Convenient image communication system was made with the technology of Intranet in addition of the DICOM network and CD-ROM changer.

It consists of Helical CT, DICOM Image Server (UNIX platforms), CD-ROM changer (100 discs) and Clients (personal computers), which are interconnected to the DICOM network via the Ethernet Switching HUB.

All the daily images produced from Helical CT are temporarily stored in the server, and then transferred to CD-R's after compression(1/10) by JPEG.

Each client makes use of a WWW browser, and asks an image server, and refers to the list of the examinations. Image indication software was started when the reference image was chosen.

The detailed images and the attribute information (patient information, examination information) of DICOM could be obtained.

The strong point of this system adopts DICOM 3.0 which is the international common standard of the image communication. And a browser for the Internet of the low cost is used of for the image observation. It has a generality, and operation is convenient, too.

It has possibility to develop to the medical information system of our institute which will be scheduled from now on.

Key words: PACS, DICOM, Intranet

Abbreviations: Picture Archiving and Communication System : PACS
Digital Imaging and Communication in Medicine : DICOM
World Wide Web : WWW, HyperText Markup Language : HTML
Joint Photographic Experts Group File Interchange Format : JPEG

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—イントラネットの応用と DICOM に準拠した新しい PACS—
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I. Introduction

In recent years there have been many studies of diagnostic image communication systems [1-4], but they greatly vary in scope and purpose from large-scale PACS (Picture Archiving & Communication System) to personal use. In the case of our department, we specialize in digestive disorders, and our inpatients and outpatients are pre-screened by referring physicians through standard medical examinations. Most of the cases are under medication, or pre and/or post surgical treatment, which usually requires detailed examination in CT scanning. We provide contrast enhancement CT (or angiography) for almost every case, and in each case we take 100 slices on average, using 9 pieces of 17" X 14" film. At this rate, we accumulate an extremely large volume of film as months go by. This imposes an enormous burden on our human and financial resources in archive retrieval and warehousing. For this reason our department has been studying a diagnostic image communication system as a way to efficiently manage the archived CT and other kind of diagnostic images, and improve their utilization.

In developing such a diagnostic image communication system, we defined our requirement as follows : maintain the film-based workflow for daily uses; utilize many available Macintosh computers as viewing stations ; take advantage of DICOM standard for common image archiving and retrieval; and most importantly, low cost. What follows is the overview of the system under development.

II. Materials and Methods

The configuration of the system is as shown in Figure 1. It consists of Helical CT (Toshiba X-vigor^{R}), DICOM Image Server (UNIX platforms: Sparc Station 20^{R}, 2GB internal hard disc and 12 GB external hard disc : Figure 2a), CD-ROM JukeBox (100 discs : DRM-1404X, Pioneer Electronic Corp.) and Clients (Macintosh^{R}), which are interconnected to the DICOM network via the Ethernet Switching HUB (Catalyst 2800^{R} : Figure 2b). All the daily images produced

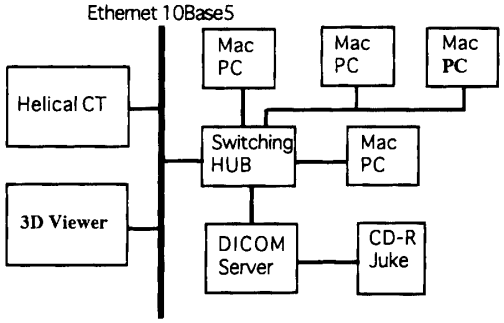


Fig 1. Configuration of our diagnostic image communication system.

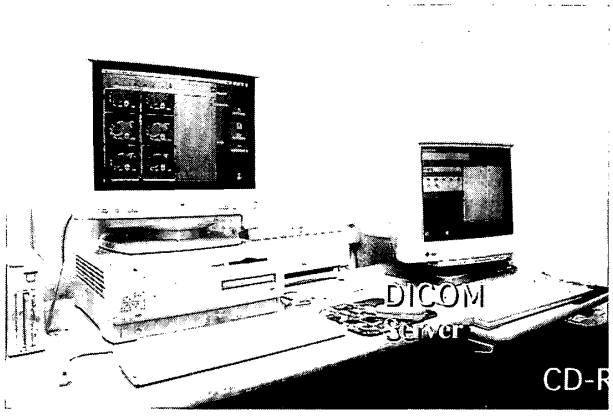
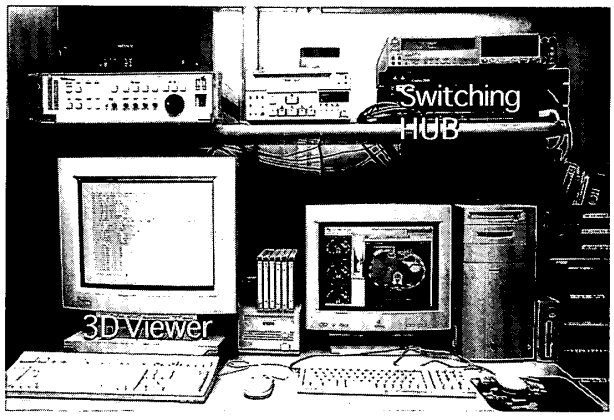


Fig 2a. DICOM image server and CD-ROM changer



2b. Ethernet switching HUB and 3D viewer

from Helical CT are temporarily stored in the server after compression (1/10) by 12 bit-JPEG, and then automatically transferred to CD-ROM's. A WWW browser (Netscape[R] 3.0 or 4.0) was used as viewing applications. Those screens are all generated using HTML on the DICOM Image Server. And a separate program (POP-Light[R] : Image & Measurement, Inc.) was used if detailed reading is necessary.

Ⅲ. Results

When reviewing images on the WWW browser, the average retrieval time from the HD is 61 seconds for 60 images. When we access images from CD-ROM, initial loading time of CD-R is about 20 seconds and the average retrieval time is 73 seconds per 60 images. The access time of images in HD and those of CD-ROM after loading CD-R are not big difference in response time. When the image server is accessed via the browser (Netscape) from each client, the initial screen (Fig 3 left) will be presented. Then retrieve the list of studies (Fig 3 middle). Specify the list name and invoke a particular patient's study (Fig 3 right). Select a series and review the list of images in thumbnail (Fig 4). A slice can be selected for further inspection at the normal size (Fig 4 left), and tag information can also be viewed (Fig 5 left).

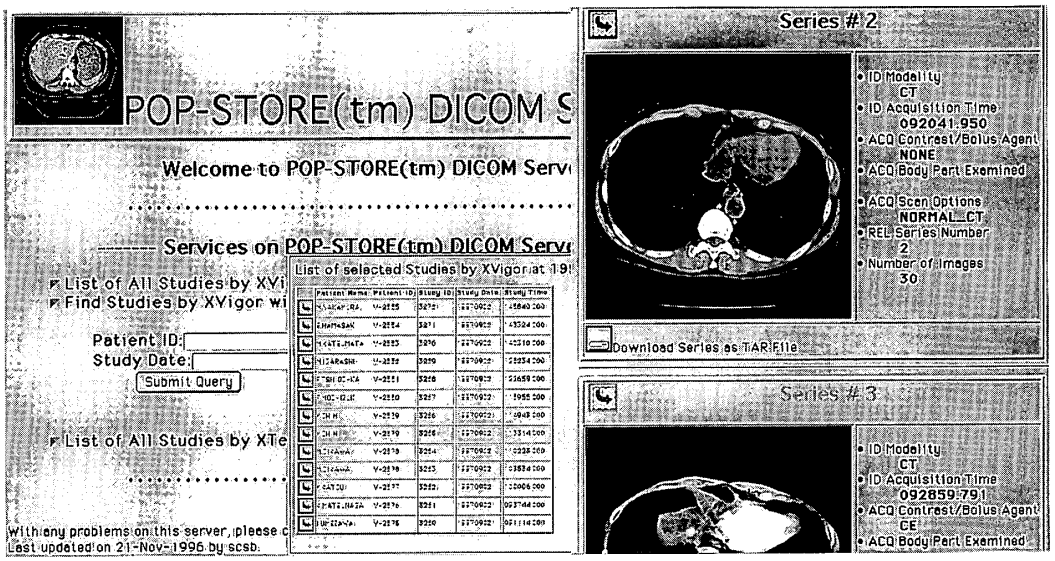


Fig 3. Browser (Netscape), left : initial screen, middle : list of studies, right : particular patient's study.

Fig 4. Left : CT Images in thumbnail (GIF), right : normal size image (GIF).

The images after compression by JPEG are showed in Fig 6. The quality of the original image and that of the 1/10 JPEG image are almost indistinguishable. That of 1/20 JPEG image is slightly poor. And that of the 1/25 JPEG image is coarse and obviously inferior to the others.

Those screens are all dynamically generated using HTML on the DICOM Image Server, which allows for flexibility in future revisions.

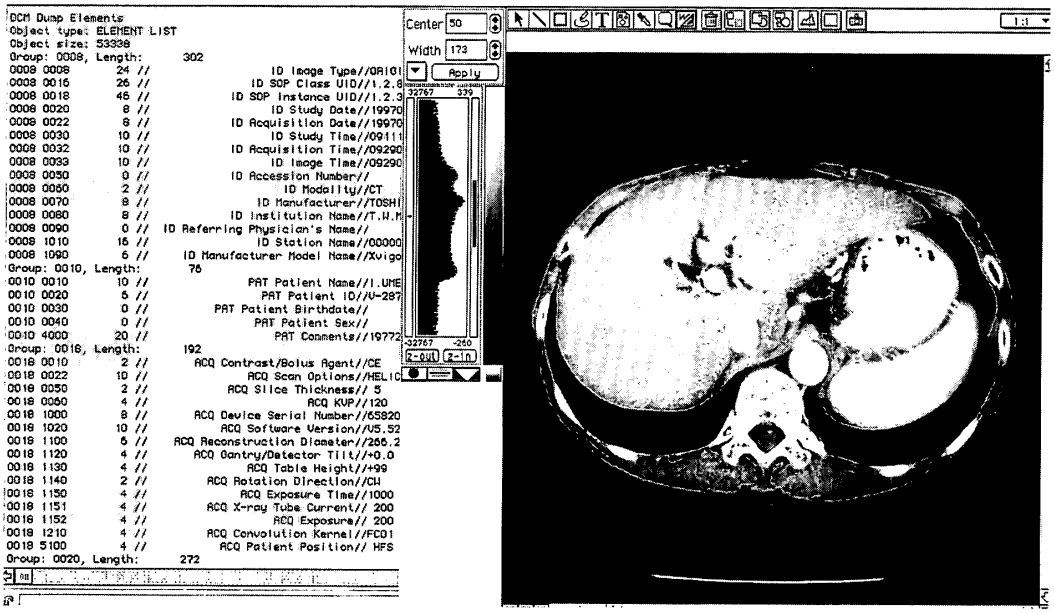


Fig 5. Left: DICOM tag, right: DICOM 12-bit image viewed with POP-Light.

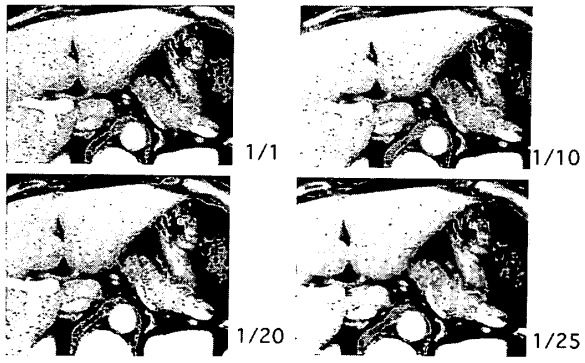


Fig 6. Comparison of image quality between original and JPEG compressed Images.

Compared to the legacy system, which also allowed for these controls, the new system is much easier to operate and presents DICOM tag information as well. When detailed reading is needed, DICOM image can be viewed with POP-Light (a separate viewing application program). Its main features among strong image processing capabilities include DICOM 12-bit image support, multiple image display by user definition, adjustment of window levels and width in 12-bit depth image, display of CT values, distance (caliper), and area measurement.

IV. Discussion

Faced with the reality of a heterogeneous mix of modalities and peripheral systems many medical institutions find themselves in, it is important to secure ease and reliability in image transfer and archiving. For this reason DICOM standard is proposed as the common digital format. DICOM (Digital Imaging and Communication in Medicine) standardizes the image file format and transfer methods of the image and its tag information[5]. This makes it possible to transfer digital images among various modalities from different manufacturers. It is primarily for CT, but this standard also broadly applies to MRI, Ultrasonography, RI, CR and imagers. DICOM devices can be interconnected through the free CTN software. DICOM's history started in 1983 when ACR (American College of Radiology) and NEMA (National Electrical Manufacturers Association) established a joint committee whose purpose was to plan digital imaging and communications in the medical field. In 1985 the committee introduced ACR-NEMA

300-1985 (Ver 1.0) as an initial standard, followed by the revised ACR-NEMA300-1988 (Ver 2.0) in 1988. In this way methods for point-to-point communication were standardized. The arrival of an Era of Network Communication, as evidenced by ubiquitous LAN and the Internet, made it crucial to update standards to allow wider coverage and enhanced functionalities in medical image communications. The new standard was approved by RSNA in 1993 and came to be called DICOM rather than ACR-NEMA (Ver 3.0).

During the 1950s computers were managed by specialists, with users using punch cards to operate them. With the onset of the 1960s, the time-sharing system enabled the use of large-size computers from the dedicated terminals. In 1969 ARPA-NET was set up under the initiative of the U.S. Department of Defense. It linked together research institutions within the military and academia. As a result a unified communications protocol has emerged. In the 1970s a distributed processing system was introduced, allowing for simple tasks and pre-processing with mini computers. In 1974 IBM introduced System Network Architecture, which established a layered protocol (standardized as OSI in 1984). Since the early 1990's the Inter net, an amalgamation of computer networks, has spread at an accelerated speed to become commonly known among the general public. An abbreviation of Internetwork, the Internet is now a worldwide communications base, linking as many as 20000 networks in 150 countries. In the latter half of the decade the Intranet, an offshoot of the Internet, is attracting attention and showing rapid growth. The Intranet employs Internet-based tools such as e-mail, file transfer and Web browse in the internal network systems of respective organizations. A marked advantage of the Intranet lies in the low-cost procurement of constantly-updated software, by taking advantage of software widely available on the Internet. In fact, we updated from Netscape 2 to 3 during the development and we are currently about to adopt Netscape 4. Previously, any system modifications necessitated a major financial investment. Although we ourselves considered a proprietary system, it became clear to us that the Intranet technology will be very effective in developing a diagnostic image communication system for the above reasons. Our system will be, however, more resource-intensive compared to the traditional Intranet with text-based information such as e-mails, because of the massive volume of image data involved. WWW (World Wide Web) technology is best suited to handle images in the Intranet, but there had been no system that can handle DICOM images in the WWW setup before. We adopted POP-STORE Server System (developed by Image & Measurement, Inc.) which addressed this issue[6]. The next big problem was image storage and archiving. It is critical to manage the large volume of images generated on a daily basis. Those images are not just read once; in CT image reading we usually compare them with previous images. The average age of case histories varies from institution to institution, but in our case comparison to previous images taken 1 or 2 years ago is not uncommon. We therefore considered hard disk drives as the storage medium. This satisfies the retrieval speed requirement, but it is not considered a reliable long-term storage medium. The cost of HD-based mass storage is also very prohibitive. Magnetic tapes are commonly used for data backup for computers, but the retrieval speed is unacceptably slow. CD-R, on the other hand, offers a write-once/no overwrite characteristic well suited for archival purpose.

Media are also very inexpensive. One drawback is that storage capacity per disc is limited to 600MB. Another concern was the retrieval speed. CD-R Jukebox systems have been used for database systems, but there had been no precedent with WWW servers as far as we researched. Special features of the system are its adoption of DICOM, the international standard for image communication, its employment of a cost-efficient Internet browser for image viewing, and its flexible and user-friendly operation. Up until now, browsers such as Netscape Navigator and so forth could not directly process the DICOM image. Future enhancements include search capabilities, expanded databases, improved storage media, and provisions for security issues. Although the system is far from perfect at this time, simplified image browsing should make possible its future use in the fields of clinical and educational applications. Plans are also underway for integration into conference support system. It may also open a way to an ultimate filmless operation if the problem of lossless compression can be resolved.

要　旨

DICOM ネットワークに CD-ROM changer を加えて INTRANET の技術を応用した簡便な画像管理システムを構築した。構成は，Helical CT と DICOM 画像サーバー（UNIX），CD-ROM changer（100枚）およびクライアント（Macintosh）が DICOM ネットワークに接続されている。Helical CT（Toshiba X-vigor）から出力される一日の全検査画像情報は DICOM 画像サーバーに圧縮（1／10）し保存する。その後，自動的に CD に保存する。各クライアントは WWW ブラウザ（Netscape）を活用して画像サーバーに問い合わせ，検査のリストを参照する。目的とする参照画像を選択すると画像表示ソフトが起動された。画像と DICOM 属性情報（患者情報，検査情報）の詳細な画像観察が行えた。本システムの特長は，画像通信の国際共通規格である DICOM3.0を採用している。画像観察には低コストのインターネット用のブラウザを活用している。汎用性もあり操作が簡便である。今後予定される，院内の高度医療情報システムへの発展性があると考える。

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