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Research-oriented image registry for multimodal image integration

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Abstract. To provide multimodal biomedical images automatically, we constructed the research-oriented image registry, Data Delivery System (DDS). DDS was constructed on the campus local area network. Machines which generate images (imagers: DSA, ultrasound, PET, MRI, SPECT and CT) were connected to the campus LAN. Once a patient is registered, all his images are automatically picked up by DDS as they are generated, transferred through the gateway server to the intermediate server, and copied into the directory of the user who registered the patient. DDS informs the user through e-mail that new data have been generated and transferred. Data format is automatically converted into one which is chosen by the user. Data inactive for a certain period in the intermediate server are automatically archived into the final and permanent data server based on compact disk. As a soft link is automatically generated through this step, a user has access to all (old or new) image data of the patient of his interest. As DDS runs with minimal maintenance, cost and time for data transfer are significantly saved. By making the complex process of data transfer and conversion invisible, DDS has made it easy for naive-to-computer researchers to concentrate on their biomedical interest.

Keywords: PACS; LAN; Research-oriented; Image archive.

1. Introduction

For both basic and clinical research using biomedical images, access to digital data is now becoming essential. For quantification of the signal, and for further statistical analysis or compartment model analysis, data from a limited region of interest may not be sufficient. This has been well recognized in the field of nuclear medicine and human brain mapping using positron emission tomography (PET) and O-15 water [1], and recently functional magnetic resonance imaging (MRI), but nowadays it is also true in the larger field of diagnostic radiology. Manipulation of the digital data is essential in three-dimensional reconstruction [2, 3], registration of images of different modalities [4–7], or non-frame stereotaxic intervention [8, 10], all of which enhance the diagnostic accuracy; hence even clinicians might want to manipulate the data. However, different data formats have been an obstacle for computer-naive-researchers or clinicians. Even for well trained imaging researchers, data transfer and format conversion are time-consuming and non-productive components of their work. Hence automation of the process on a general platform will enhance research productivity as well as clinical usefulness. For this purpose, we designed a computer network system to provide multimodal biomedical images for multiple research teams automatically with the necessary format conversion. We have used the pre-existing local area network, and other commercially available hardware for general network systems, to minimize the cost of construction and maintenance of the system.

2. Materials and methods

The campus local area network (LAN) of Fukui Medical School and Hospital has been constructed with FDDI (Fibre Distributed Data Interface) centred with a FDDI switch (GIGA switch, Digital Equipment Corporation, MA, USA). Their characteristics are high speed in data transfer (100 Mbps, 10 times faster than traditional wire based Ethernet) and its transfer reliability. As FDDI supports the standard communication protocol, TCP/IP (Transmission Control Protocol/-Internetwork Protocol), it is easily connected to classical Ethernet networks through Ethernet 10 base-T type connections to general users. Approximately 1000 computers (210 workstations and 790 microcomputers) are now connected to the campus LAN. Image generators in the Department of Radiology and Biomedical Imaging Research Center have been linked to the LAN. A 10 Base-T interface was used to connect image generators such as computed tomography (CT), MRI, PET, image intensifier digital radiography (IIDR) and digital subtraction angiography (DSA) to the primary server. There are three types of primary server; Data Management Unit (DMU; Array Co., Tokyo, Japan), Universal Gateway (UGW; GE-Yokogawa Medical Systems, Tokyo, Japan), and Unix-data server. DMU is used to connect Ultrasound (GE-Yokogawa Medical Systems, Tokyo, Japan), IIDR (Hitachi Co., Chiba, Japan), DSAs (Philips, Best, Netherland, and Siemens, Erlangen, Germany) to the LAN. DMU copies image information sent to the laserprinter; hence there is no interference to the routine clinical services. UGW connects PET, CT, and MR (GE-Yokogawa Medical Systems, Tokyo, Japan) to the LAN. UGWs store all information from the generator with conversion to NEMA 2 format in a temporary buffer of 800 MB. SPECT (Toshiba, Tokyo, Japan) is directly connected to the LAN, and automatically transfers image information with NEMA-like format to the UNIX data-server.

Data Delivery System (DDS) is a network application written in C language on UNIX (SUN Microsystems, California, USA), utilizing the telnet utility. Additional hardware required other than network infrastructure were SPARC 5 (SUN Microsystems, California, USA) equipped with 9 Gigabyte hard disk, and compact disk (CD) changer of 1 Terabytes capacity (Pioneer, Tokyo, Japan). Its functions are: (1) periodic search of the images of registered subjects in the primary servers, (2) transfer of the image data followed by appropriate format conversion, (3) notification to the users through e-mail, and (4) archiving the data which is inactive for a certain period.

Once DDS obtains registry information from each user through telnet, it periodically (6 times per day) searches for the particular data in the primary server. It transfers the data into the directory of the user on the secondary server of 9 Gigabytes capacity with conversion to a specified data format. DDS is now supporting NEMA2.0, ANALYZE (BIR, Mayo foundation, Rochester, USA), AVS (Advanced Visual System Inc., MA, USA) and NIH images. DDS automatically changes the access mode of the data for the authorized user in order to protect the data. Once these processes have been completed, DDS sends e-mail

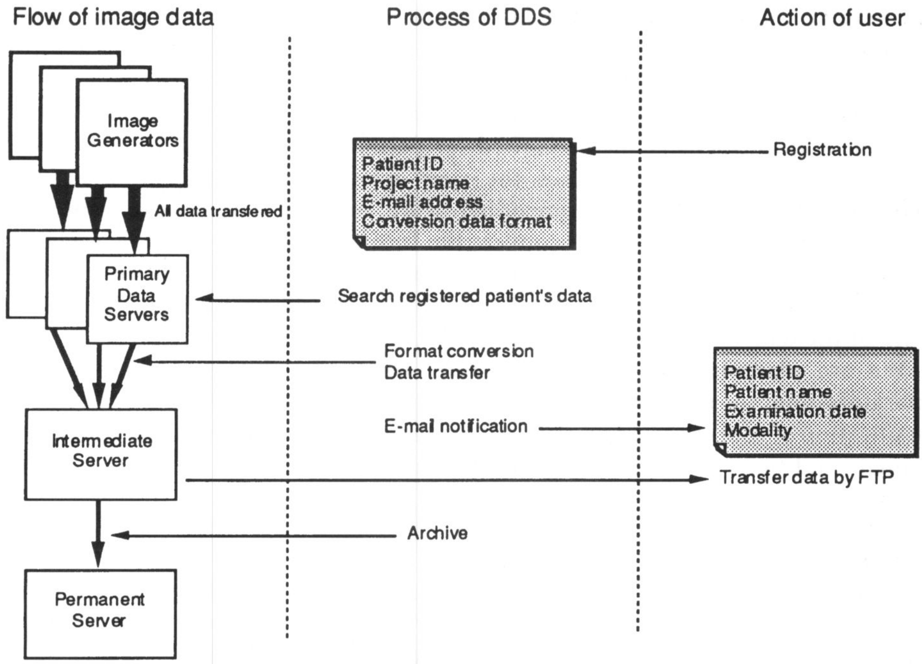

Figure 1. Functions of DDS. All the generated image data are transferred to primary servers in which DDS filters the necessary data based on the registration information provided by users. Selected images are copied too the intermediate server from which notified users can transfer their converted data. Old data are archived in the permanent server.

notification to the user. Data inactive for a certain period in the secondary server are automatically archived into the final and permanent data server based on compact disk. As a symbolic link is automatically generated through this step, a user has access to all (old or new) image data of the patient of his interest.

Once users receive e-mail notification that images of his interest are generated, he can transfer the format-converted data from the second server using the ftp (file transfer protocol) utility (figure 1).

3. Results

During a 6 months trial period, 20 projects and 50 researchers were included. Two hundred and thirty patients were registered, and approximately 8 Gigabytes of image data were stored in the intermediate server. Through this trial period, DDS ran automatically, with minimal maintenance by one system operator. A process of searching 11 image generators took approximately 15 min, without affecting the overall network performance.

4. Discussion

Advantages of this system are automatic data transfer and data conversion which the user does not have to be aware of. It is not difficult to automate the transfer from the intermediate server to the user's workstation or personal computer. To increase user choice, however, we decided that the last portion should be done manually;

they may not need the particular image sets, or disk space may not allow them to transfer the whole dataset. Actually manual operation was shown not to be a burden for the users.

This system requires minimal maintenance cost, because there is no need for an operator, and inexpensive media is used for permanent archive (CD). As DDS is independent of the client machines, the users' investment is minimal. There is no need to purchase particular software or hardware. As there is no need to transfer the original data to the local disk to convert the format, local disk space is saved. By interactive processing, users can proceed with the registration process without referring to a manual. E-mail notification is particularly useful to make the user aware of the data acquisition condition of the users' particular concern.

We are planning to expand the DDS system by connecting more image generators and by supporting more data formats such as DICOM. In future, classification of users (beginners to image professionals) may be necessary to provide optimal conditions and options for their research.

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