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The Mobile Terminal System Implementation of Medical Imaging based on Motion-JPEG

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ABSTRACT

The mobile terminal system plays a key role in medical industries which require in fast and accurate diagnosis from heterogeneous acquisition equipment. The demand for PACS (picture archiving and communication systems) has continued to increase in major hospitals and private clinics. Patient care depends on how fast the medical imaging system provides images and how accurately the images are interpreted by physicians. In this paper, we propose an efficient method to decipher the hundreds of images required by physicians to accurately diagnose patients. By exploring Motion-JPEG (M-JPEG), this paper has demonstrates the possibilities for efficient management of medical images with a newly designed image file format and improvement in imaging diagnoses through the replaying of moving pictures of a patient in a mobile environment.

Key words: Mobile terminal, Motion-JPEG, PACS system, DICOM

1. INTRODUCTION

PACS (picture archiving and communication systems) transmits and receives a DICOM (digital imaging communication in medicine) image in a network environment. The demand to utilize medical images and information stored by high-capacity memory equipment is increasing in the wired/wireless Internet environment using PC or mobile terminals. The data transmitted in hospitals requires processing of significantly high-capacity images. In this kind of environment, physicians need to invest a lot of time to analyze medical images. To improve this process requires technology to compress and playback moving pictures with hundreds of medical images. M-JPEG is a potential candidate to implement the technology with these hundreds of pictures, [1,2].

M-JPEG uses intraframe coding technology that is very similar in technology to the I-frame part of video coding standards. This algorithm uses DCT and the quantization method to remove spatial redundancy. This means that the medical images can be thought of as I-frames. M-JPEG is also commonly used in internet blog, a design of the background for mobile terminals or moving picture imaging [3]. Fig. 1 shows the interface of PACSPLUS, a DICOM image viewer from Medical Standard [4]. PACSPLUS can playback moving pictures with each DICOM image. This paper attempts to demonstrate a method to improve the efficiency of management and transmission by using the M-JPEG file format.

PACS will store DICOM objects and data from all the enterprise's information systems, including radiology, laboratory, cardiology, billing, and other administrative applications. Fig. 2 shows an overview of a full PACS system. It describes the

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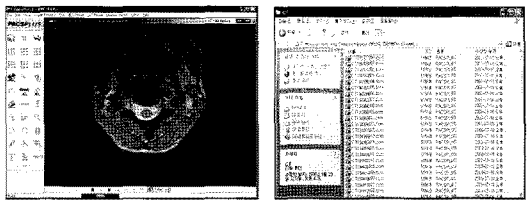

Fig. 1. The PACSPLUS solution from Medical Standard.

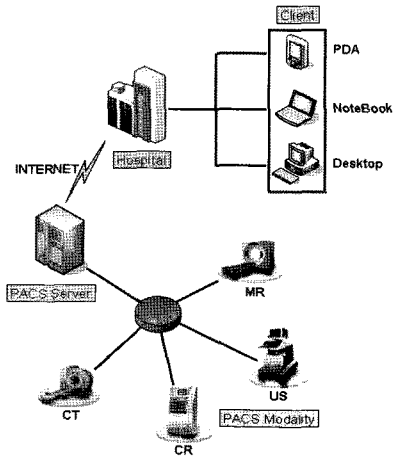

Fig. 2. A general PACS system.

PACS' ability to capture X-ray, MRI, CT and ultrasound images in a digital format and allow these images to be accessed by physicians via computer for immediate diagnosis. DICOM is a standard communication protocol that has been adopted in PACS. In general, DICOM specifies that image information represents an Information Object which is defined in the Information Object Definition (IOD) [5]. Such an IOD includes attributes such as the patient's name, the examination type, the date and etc. The attributes of an IOD describe the properties of a Real-World Object Instance. The related attributes are grouped into modules which represent a higher level of semantics documented in the module specifications found in Annex C of the DICOM standard. The command words relate to Service Classes which are defined in the DICOM Message Service Element (DIMSE). Attributes are encoded as Data Elements using the rules, the Value Representation, and the Value Multiplicity concepts specified in PS 3.5 of the DICOM Standard. For specific Data Elements, the Value Representation and Value Multiplicity are specified in the Data Dictionary in PS 3.6 of the DICOM Standard. Table 1 and 2 show examples of a patient IOD with some modules and a patient identification module with some attributes.

With a rapid development of mobile devices, the medical areas are being incorporated and adopted to PACS. In most of medical information transmission applications, they utilized image based communication over wireless and wired network. Among many studies, Andrade et al. [6], Ishikawa et al. [7], and Polyxronopoulou et al. [8] investigated and presented the data visualization and communication based on medical image transmission. Even though there are limitations to visualize the all medical information, they are useful to analyze and

Table 1. The example of a patient IOD

Module	Module description
Common SOP	SOP contains the common information.
Patient relationship	Refer the related patient SOP
Patient identification.	Identification of a patient
Patient description	Description of patient information
Patient diagnosis	Medical examination information

Table 2. An example of patient identification modules

Attribute	Tag	Description
Name	(0010, 0010)	Patient name
Patient ID	(0010, 0020)	Patient ID or code related hospital identification
Issuer of patient ID	(0010, 0021)	Facility name issuing patient ID
Birthname	(0010, 1005)	Patient birthname
Mother's birthname	(0010, 1060)	Mother's birthname
Medical record material identifier.	(0010, 1090)	Identifier to find the previous medical record

diagnose the patient's status. However, this paper proposes the continuous variation of the patient diagnosis. This feature helps physicians to diagnose a detailed and complete analysis. In this paper, we propose a motion JPEG based medical data communication system that enables medical image analysis using mobile devices.

2. M-JPEG (Motion-JPEG)

M-JPEG technology compresses each video frame into a JPEG file format and deals with JPEG compression/restoration in real time. It is also applied to the motion picture compression method with still images. M-JPEG is based on a JPEG image, and relies on the moving picture streams listed between JPEG frames for time information [9,10]. As a standard is not fixed, each vendor is develops their codec independently unlike M-JPEG2000. Related codecs can be found made by Pegasus (http://www.jpg.com/pvmjpegdownload.htm) and Morgan Multimedia (http://www.morgan-multimedia.com/technicalsV3.htm). Since the implementation of M-JPEG is easier than that of other moving picture file formats, it can be used for processing, reading, encoding, transforming, decoding and displaying image data. In the case of medical applications, the image quality, which is one of the most important issues, has been uniformly maintained regardless of the data complexity. While M-JPEG has shown some disadvantages relating to compressibility or large amounts of data, such problems can be overcome by developing M-JPEG2000 [11-13].

2.1 JPEG

The JPEG standard for image compression is comprised of a toolkit that has three distinct components: baseline lossy, extended lossy, and lossless. A baseline lossy JPEG - the most widely implemented of the three different approaches, utilizes the discrete cosine transform to decompose an image into sets of spatial frequency coefficients. The characteristics of JPEG2000 [8,9] can embody the lossy and lossless compression at the same time in one encoded bit stream, and has shown itself to be higher quality than the existent JPEG format with the high compressibility.

JPEG is currently used in various ways in hospitals - from before/after comparisons of surgical procedures at skin clinics to the transmission of optimized JPEG images over the Internet. For example, a foreign company by the name of GENESIS Digital Imaging, Inc., (http://www.genesisdigital.com/medwebpacs.php), developed the Omni-WEB PACS which uses a JPEG compression technique. In domestic hospitals, PACS solution MAROSIS from Marotech, Inc. has been implemented in EulJi university hospital with the JPEG2000 compression technology and has proven the high image quality it can provide. The web-based PACS solution named STARTPACS.net from Infinitt, Inc. (http://www.infinitt.com), has been applied to the JPEG2000 compression in low bandwidth environments and has shown efficient image display.

2.2 Design of M-JPEG File Format and Transmission Packet

There are many approaches possible in order to implement M-JPEG compression, however, the best idea is to make one M-JPEG file with multiple JPEG images. This is because there is no specific M-JPEG file format. A JPEG image is included as the marker regarding information related to the output and compression of an image in files. The marker indicates the starting part as a SOI (start of image, 0xffd8) and the ending part as EOI (end of image, 0xffd9). The file format is reconstructed by putting the frame header information before the JPEG frame. The information detailing the amount and dimension of the JPEG image is stored in the frame header. The file header contains the string 'MJPEG' showing the M-JPEG file identification,

the whole size and the number of frames. Fig. 3 shows the proposed M-JPEG file format. The M-JPEG file has an advantage for network transmission because it contains the header information. In addition, it is possible to determine the file information using only the header information. For example, when we have 300 DICOM images and each image is 516KB, the total amount of DICOM images becomes 154MB. As a result of the encoding process to an M-JPEG file, the size of the DICOM image is reduced by 27KB and the total amount of a single M-JPEG file is reduced by 8MB. Since the application program correctly distinguishes the allocated process and figures out the memory size, it is necessary to design the packet structure as shown in Table 3, 4 and Fig. 4.

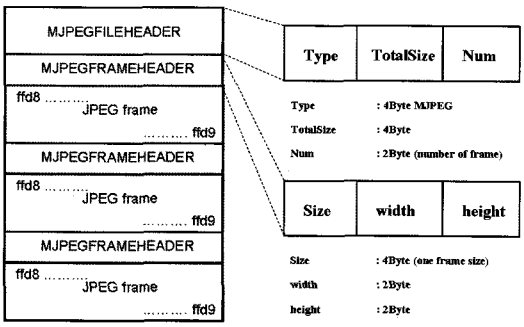

Fig. 3. M-JPEG file format.

Fig. 4. A simple packet structure.

Table 3. A Network Packet

	Size	Description
Type	1Byte	PACKET_CONTENT PACKET_MJPEGFILEHEADER PACKET_MJPEGFRAMEHEADER PACKET_MJPEG PACKET_MJPEGLIST PACKET_MJPEGSELECT PACKET_MJPEGLISTCHAGE PACKET_NOFILE
Size	4 Bytes	Size of image
Data	4500 Bytes	MJPEGFILEHEADER MJPEGFRAMEHEADER Image data MJPEG file name

3. THE EXPERIMENT AND DISCUSSION

M-JPEG is a kind of moving picture streaming technology utilizing a JPEG compression scheme for each frame. In general, the end user downloads the encoded moving picture file from the Internet or another network and plays it back in real time. The M-JPEG system also offers other functions such as the management of encoded DICOM images and playback of the transmitted M-JPEG files. Fig. 5 shows the diagram of an M-JPEG system. In order to implement these systems, three parts are applied. Table 5 describes the implemented modules of the M-JPEG system.

In our experiment, the proposed system employed the M-JPEG coder for a personal computer with an Intel Pentium 4 running the Windows XP

Table 4. A packet description

PACKET	Description
PACKET_CONNECT	The server delivers the connectivity to the client
PACKET_MJPEGLIST	Transmission for M-JPEG file list managed on a server
PACKET_MJPEGLISTCHANGE	Notification for the changes of M-JPEG file list on a server
PACKET_MJPEGSELECT	The client requests the M-JPEG file from a server
PACKET_MJPEGFILEHEADER	Transmission of M-JPEG file header information
PACKET_MJPEGFRAMEHEADER	Transmission of M-JPEG file frame information
PACKET_MJPEG	Transmission of M-JPEG packet information
PACKET_NOFILE	Notification of the requested file existence

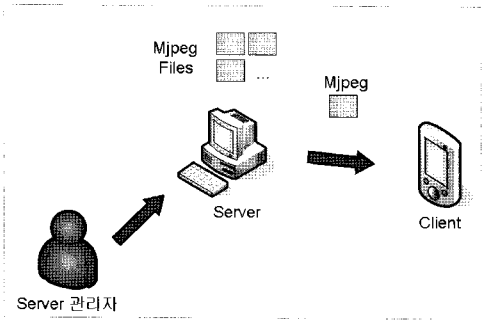

Fig. 5. The diagram of M-JPEG system.

Table 5. The implementation of application program modules

Module	Description
M-JPEG Encoder/Decoder (PC)	A server manages the generation and management of a M-JPEG file from a series of DICOM images
M-JPEG Server (PC)	A server transmits a M-JPEG file according to the client's request
M-JPEG Client(PDA)	A client decodes and display the transmitted M-JPEG file.

OS. For the implementation of application development, we used Visual C++ 6.0 and the MFC (Microsoft Foundation Class) library for the UI(User Interface). A PDA which served as a client used Embedded Visual C++ 4.0 MFC to Windows CE Pocket PC 2003 environments, and used a VOImage library for JPEG output.

3.1 M-JPEG Encoder

In order to encode the DICOM images to an M-JPEG file, we first converted a set of images to JPEG format using the Intel library IJL version 1.5. The hundreds of DICOM images were stored sequentially in the designated file folder and a server generated the encoded file in the M-JPEG format by connecting the starting and ending marker of each JPEG image. At this time, the MJPEGFRAMEHEADER was placed between the MJPEGFILEHEADER and the JPEG image. The M-JPEG file was generated by completing this process. Fig. 6 describes the M-JPEG encoding

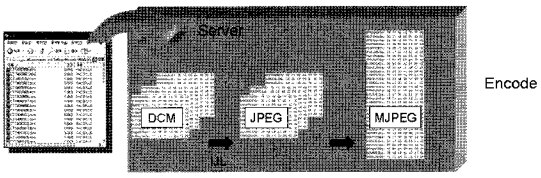

Fig. 6. The simplified description of M-JPEG encoding process.

process.

For further clarification, when we executed the implemented application program described in this paper, we did so through a user interface window. Once we selected the [M-JPEG] and [Encode] from the pull-down menu, the dialog box popped open as shown in Fig. 7.

The application programs allows us to indicate the file information needed to generate the M-JPEG file - the path of the selected folder containing the DICOM files to encode, a file name, and whether it is the right DICOM file or not. The fundamental path to be created for the M-JPEG file can be designated by pressing the MJPEGFiles or [path setting]. Fig. 8 shows the encoding setting

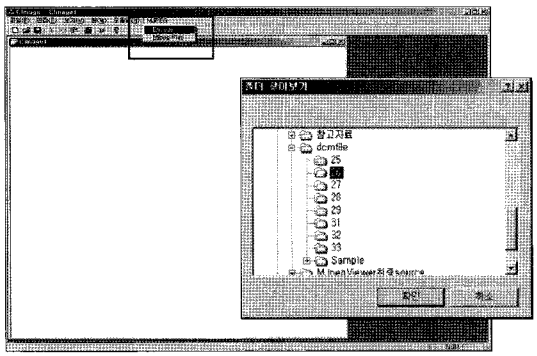

Fig. 7. The example of user ineterface on an encoding process.

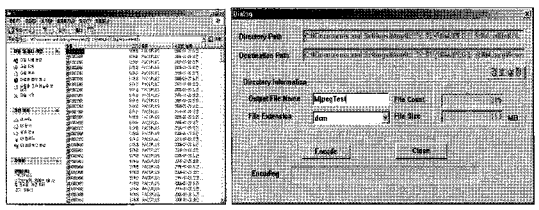

Fig. 8. The setup for encoding environment.

process. Completing the steps of the encoding process results in the generation of the M-JPEG file as shown in Fig. 9.

3.2 M-JPEG Decoder

In order to playback the M-JPEG moving picture, the user loads the M-JPEG file from the application program viewer. Using the simplified linked list algorithm as shown in Fig. 10, the generated file shows the efficiency for playback and the selection of the interested frame. After a user selects the M-JPEG file to be decoded, the user chooses the menu [MJPEG] → [Play MJPEG] and the selected file is played back. Fig. 11 and 12 show a captured image of replaying the implemented M-JPEG moving picture.

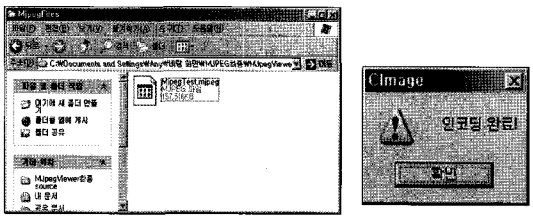

Fig. 9. The M-JPEG file generation.

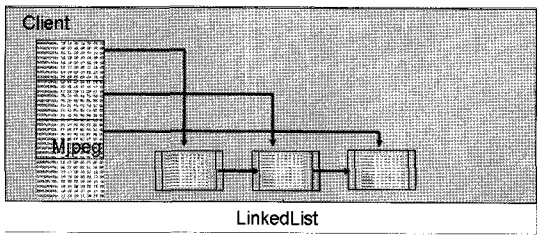

Fig. 10. The M-JPEG decoding process.

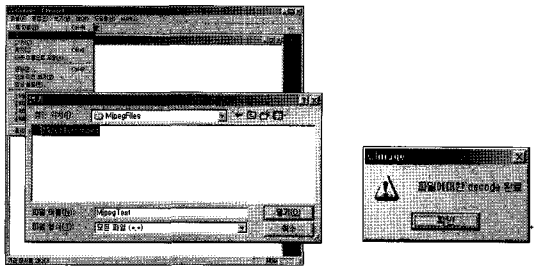

Fig. 11. The selection of M-JPEG file to be decoded.

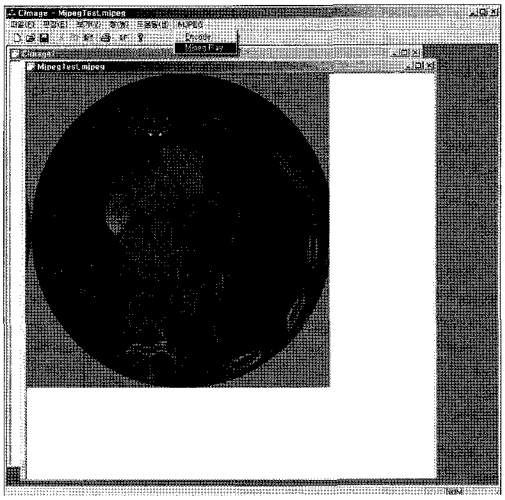

Fig. 12. The replay of the implemented M-JPEG file.

3.3 Server application program

The server application manages the addition and the deletion of the relevant files and folders and automatically communicates with the client. Table 6 shows a description of the server's actions. Fig. 13 shows an example of the server execution.

When a client is connected, the server displays the client information. If the M-JPEG files need to be updated, the server manager notifies the client of the updated information by prompting the user to click the [Update MJPEG]. The directory to manage the M-JPEG files is located in the project folder.

Table 6. The description of server functions

Module	Description
Execution	Load and display of M-JPEG file information
Initiation	Prepare the request of the client's access
Access and disconnection	Monitor the real-time access and disconnection of the client
Change of the M-JPEG list	Notify the list change/modification to the connected client
Communication	Communicate with a client without user input automatically.

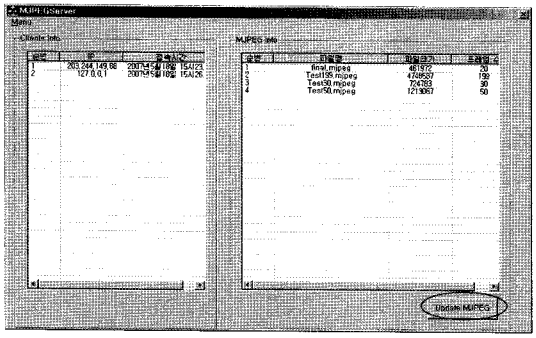

Fig. 13. The connection information between a server and client.

3.4 Client (PDA) application program

A PDA client initiates activation of a server by requesting work. Table 7 describes the client application functions. The Fig. 14-(a) shows the initialization stage after receiving a PDA request. This screen capture utilized Cerdisp (remote display control application from Microsoft) to monitor the real-time PDA process. After clicking the [Connect] menu, the application program displays a dialog box prompting the user to input the server IP and port number in Fig. 14-(b). From the [MJPEG List] menu, the program displays the transmitted M-JPEG files as shown in Fig. 14-(c).

Table 7. The description of client functions

Module	Description
Execution	A client is executed
Access to a server	Connect to a server with IP and port information and wait the packet whether it is connected or not
Access completion	If the access is completed, the client gets from a M-JPEG list and stores to a M-JPEG list Dialog from the server.
Notification of the updated list	If updated, a client gets the new information.
Display the M-JPEG list dialog	Display a list to identify the M-JPEG files
M-JPEG file selection	Select a M-JPEG file and transmit the relevant file to the server.
Display	Display the M-JPEG file

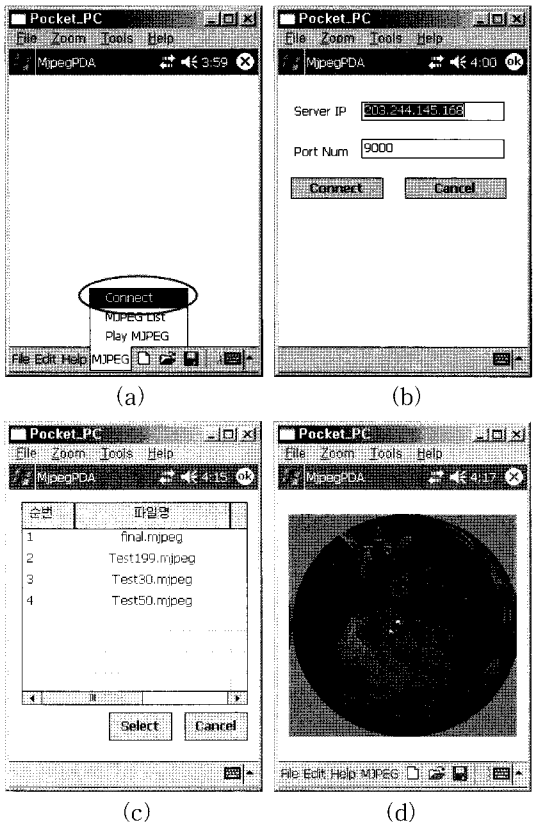

Fig. 14. The operation procedure of PDA client: (a) The initial screen, (b) server access, (c) search list for M-JPEG files, and (d) replay.

Each file contains the file name, file size and the number of frames. In order to display the selected M-JPEG file, it plays back the created moving picture. Fig. 14-(d) shows one snapshot from the moving picture.

In our experiment, we used 300 frames of CT heart images (each 516KB) and 320 frames of MR renal images (each 514KB) formatted by DICOM standard and reproduced as a M-JPEG file. The encoding, decoding and playback time showed 30 seconds, 4 seconds, and 27 seconds respectively. In the PDA environment, the experiment resulted in a bit of interruption with the limitations caused by PDA performance in comparison to a desktop PC. Since the DICOM images are acquired and assured seamlessly by the acquisition equipment, there will be no inconvenience for the physicians.

4. CONCLUSION

In this paper, we implemented a server-client system to provide moving pictures from hundreds of medical images in a mobile environment. In medical image processing, M-JPEG technology might result in some loss in image quality in comparison with other codes like MPEG-4 or H.264 if the difference between frames is bigger and bigger which result in some loss of the computation of the motion vector. However, we our experiment demonstrated the capability M-JPEG to achieve fast and efficient to diagnoses utilizing hundreds of images. With improved hardware performances, the M-JPEG format can be applicable in an ubiquitous environment using mobile terminals. In addition, optimization of compression to make a moving picture should always be considered in medical areas.

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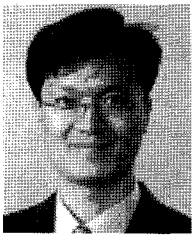

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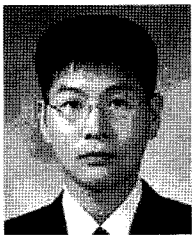

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