Tablet PC as a Mobile PACS terminal using Wireless LAN

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ABSTRACT

A PACS mobile terminal has applications in ward round, emergency room and remote teleradiology consultation. Personal Digital Assistants (PDAs) have the highest mobility and are used for many medical applications. However, their roles are limited in the field of radiology due to small screen size. In this study, we built a wireless PACS terminal using a hand-held tablet-PC. A tablet PC (X-pilot, LEO systems, Taiwan) running the WinCE operating system was used as our mobile PACS terminal. This device is equipped with 800×600 resolution 10.4 inch TFT monitor. The network connection between the tablet PC and the server was linked via wireless LAN (IEEE 802.11b).

Keywords: PACS terminal, wireless network, Window CE.

1. INTRODUCTION

Personal Digital Assistant (PDA) has the advantages of lightweight and high mobility. Due to this advantage, there were many medical applications that used a PDA. However, the small size display window of a PDA also restricts its application in displaying clinic medical images. As the technologies of the mobile device are improved, a tablet PC has 800 by 600 display has been manufactured. A larger display together with the high mobility can better meet the requirement of displaying the clinical images in the wireless environment.

In this study, we built a wireless PACS terminal using a tablet PC. Our implementation used the Leo X-pilot (Leo System, Taiwan). The tablet PC is equipped with a PCMCIA wireless LAN card (IEEE 804.11b). This LAN card provides up to 10M Bytes per second transmission of data. The tablet PC retrieves images from a database through the Internet and displays the images on the tablet PC. Since the communication is based on the Internet, the system works if it can connect to the Internet by any other means, for example by means of GPRS or PHS mobile phone. When the mobile phone system is used, the communication bandwidth restricts the application to transfer small size images through network.

The system can be used whenever the physicians need to access clinic images but a PACS terminal is not available. One possibility is to use the system in the ward round. The other possible application is in the emergency services. Physicians can bring a tablet PC and access the required images through the network.

In the idea case, the tablet PC accesses the hospital database, retrieve images, and display images. In this study, for the security reasons, we designed a two layers system. The developed system is isolated from the hospital PACS database. The system has a DICOM reader that reads DICOM images and stores the images to a local SQL database system in the other form. The tablet PC then retrieves images from that database and displays the images.

2. ENVIRONMENT

The specifications of Leo X-pilot are stated in the following. The CPU of the X-pilot is an Intel StrongArm running at 206 Mhz clock. The operating system is WinCE 3.0. Flash ROM and SD-RAM are respectively 32M bytes and 64 M bytes. Display is 10.4” TFT LCD. There are two slots, one is for PCMCIA and the other is for compact flash card. The communication can either use a LAN card or a Modem. We used a wireless LAN card. The input device is the stylus and screen. There is a desktop personal computer that serves as the image database and the server. The X-pilot is the client.

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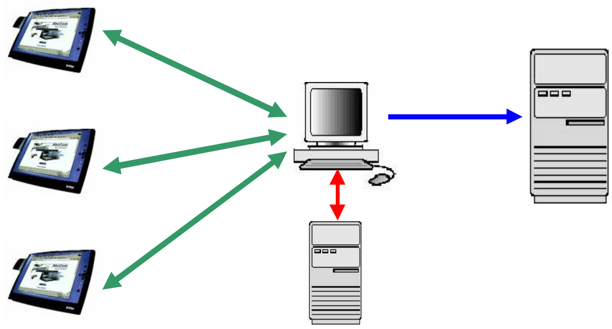

Figure 1. The server access DICOM image from PACS database (right). The DICOM parser converts the images to the desired format and stores the images to a local database (below). It connects to tablet PCs (left) though wireless LAN.

The development process was carried out in the Department of Computer and Information Science, Chiao Tung University, Taiwan. The department has had the wireless environment built up. Access points cover all the department offices and laboratories. The system is as shown in Figure 1.

3. SYSTEM DESCRIPTION

There are three modules in the system, namely, the client, the server, and the image database modules. The tablet PC is at the client end. The client sends request to the server, for example, to request for an image. The server retrieves the image from the database and sends the image back to the client through the wireless network. We briefly describe each component in the following.

Server

The server module consists of two major components, the network component and the local database component. The database component consists of a DICOM parser and a SQL database system. The DICOM parser reads DICOM files and extracts a set of keys and the images. The images are then stored into the SQL database based on the set of keys. The network component is responsible for the network communication. The methods (programs) implemented in this component wait for the requests from the clients and send images to the client upon request.

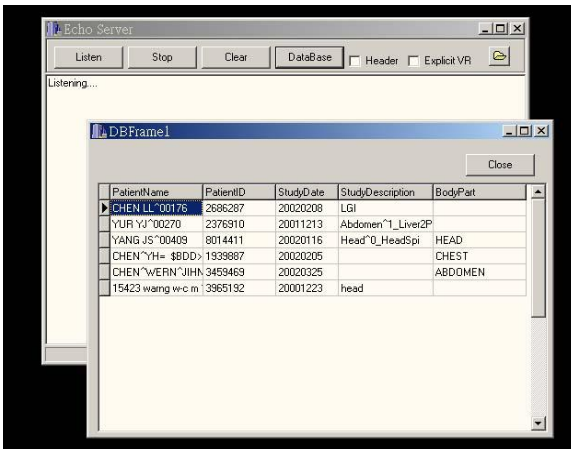

Figure 2. A screen shot of the server.

Client

There are three major components in the client site, the GUI component, the Image Tool component, and the Network component in the client (the tablet PC) site. We present each component in the following.

The GUI Component

All the window objects, such as windows, buttons, etc., displayed in the tablet PC screen are generated by the programs in this component. There are other programs that take care of the user interactions such as a stylus touching the screen and the responses to these actions are also implemented in this component.

The Image Tool Component

The programs in this component manipulate the images. These operations are designed based on the requirements of the physicians. These operations are listed in the following.

1. Images display and gray scale transformation:

Images are gray scale images (MONOCHROM1 and MONOCHROM2) and RGB color images. The tablet PC supports displaying true color images and 256 gray scales for monochrome images. The gray scales in MONOCHROM1 and MONOCHROM2 in the original DICOM file are generally more than 256 gray scales. To adjust a larger interval of gray scales into 256 scales needs a gray scale transformation (such as window/level transformation). The gray scale transformation generally needs floating point multiplication operations. Considering the computing power of the CPU in the tablet PC is not strong enough, we pre-compute a look up table for such transformation. To calculate the look up table, we employed the Bresenham's line drawing algorithm. This algorithm eliminates the floating point multiplications to reduce the computing time.

2. Positive and Negative image transform

This function is designed to display an image in either negative or positive way depending on the preference of physicians.

3. Fit an image into the screen

The screen of the tablet PC has resolution 800 by 600. The size of a CR image is much larger than the screen size. In order to observe the whole image in one display window, it is required to resize the image to fit into the display window. In our implementation, even the display image has less resolution, the client site holds the original full size image.

4. Zoom in the display image

Since the resolution of the image is reduced, some details cannot be visible unless the resolution is restored back to the original resolution. The operation zoom in] a small region is implemented so that investigation into a small region is possible. The zoom in operation is implemented as the follows. The region that will be zooming in is selected by touching the center of the region by using the stylus. A 400 by 400 region is then displayed in the original resolution.

5. Image rotation

Since the dimension of the display window is 800 by 600, the best way to fit an image into the screen is to rotate the image by 90 degree. Image displayed in this way provides better resolution for viewing.

6. Ruler

To measure the distance between two points is often required when extracting of quantitative information is desired. We have implemented this function in this system. We calculate the distance in terms of the number of pixels between two points in the display window. We then convert the pixel size into the actual distance by considering the scaling factor. The pixel size in the image of original resolution can be obtained from the DICOM header.

7. Mark on the images

For teaching or discussion purpose, it is sometimes desired to draw on the screen. This function is implemented in the system.

The Network Component

The programs in the network component handle the communications between the client and server. Each object in this component has a corresponding one in the server's network components. In order to prevent the resources (computing power) been tied up by the network components, this component is implemented using the multi-thread and event driven techniques. The network communication can be implemented using the techniques such as Socket, COBRA, DCOM, or RPC etc.. In this work, the communication between server and client was implemented using the Win socket technique. The Win socket technique has the advantages of efficiency in communication speed. The disadvantage is that it is harder to maintain comparing to that use of CORBA and DCOM techniques.

4. RESULT

In this section, we present some screen shots from the tablet PC. These figures were taken by using Nikon Coolpix 950 digital camera.

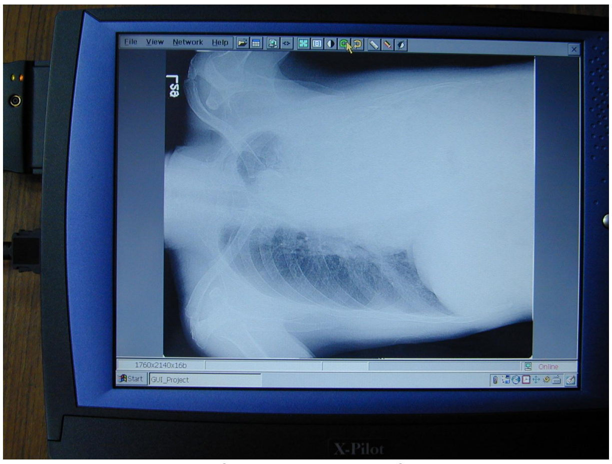

Figure 3. Rotate the image for 90 degree to fit into the display window.

Figur4. Display an image in the original resolution. Only a part of the image can be shown in the screen.

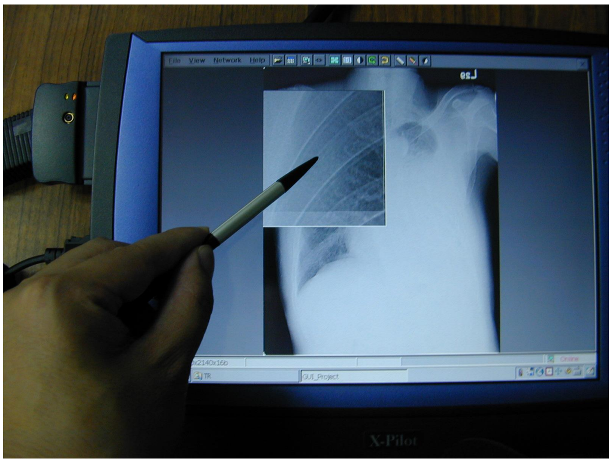

Figure 5. Zoom in into the region of interest. A 400 by 400 region is displayed in the original resolution.

Figure 6. Draw a line and calculate the true distance of the line.

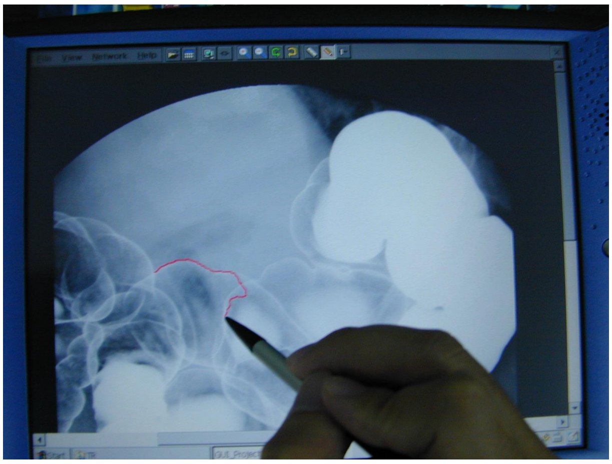
Figure 7. Mark on the image.

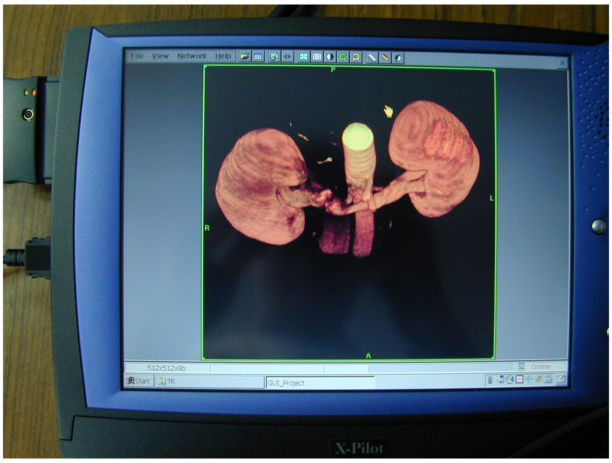

Figure 8. Display a true color image in the tablet PC.

Since the LEO X-Pilot runs WIN CE 3.0 operating system, the software development environment for the client site was the Microsoft embedded Visual Tools. There are eMbedded Visual Basic 3.0 and eMbedded Visual C++ 3.0 in this tool. We used the eMbedded Visual C++ 3.0. A standard C++ programming language with the Windows CE Application Programming Interface (API) were used.

The server is a desktop computer running Win2000. We used Borland C++ Builder 5.0 to develop the system. The database was implemented using the Microsoft SQL Server 7.0.

Some of the experiments for performance evaluation were done in the 3rd Engineering Building, National Chiao Tung University, Hsin Chu, Taiwan. In these experiments, several kinds of images are tested. The size of the images could be as large as 7.3 M bytes. We evaluated the time required for the images transmission and display. The results are as shown in Table 1. In this table, the time for data transmission is the time taken by the network transmission. The time for image processing is the time to compute the displayed image to be shown in the display window. We recorded this time since the CPU of the tablet PC generally does not have strong enough computing power. According to our result, the data transmission time is the bottleneck to display an image. The network speed, although the bandwidth can reach 10M Bytes per second, the true performance still depends on the traffic of the network. In the best case, the speed could reach the maximum speed of 10M bytes per second. In most of the cases, the performance cannot reach the best possible speed.

Table 1 The performance for displaying an image for different modalities

	Resolution	Image size	Time for Transmission	Time for Image processing
CR	1760*2140	7359 KB	27.24 sec	2.12 sec
X-Ray Radiofluorosopic	1280*1024	2561 KB	9.19 sec	1.69 sec
CT	512*512	515 KB	2.17 sec	1.22 sec
Secondary Capture	512*512	770 KB	2.78 sec	0.52 sec

5. CONCLUSION

We built a wireless PACS terminal using Leo X-Pilot. The performance was restricted by the network communication speed. The speed of the network should be improved in order to have this system applicable. Another possible approach is to compress the images if image compression is allow. If Jpeg image compression is used, the CPU computing power could be a problem again.

The light-reflection of the screen is a problem. Depending on the direction of the light source, there are viewing angles that the images is hard to read. Battery life is another problem. In most of the cases, the battery could not last long to five hours as that was stated in the specification. Batteries of a notebook computer or a PDA can be last longer if we decrease the brightness of the display. But in the clinic application, we need the displayed image to be sufficiently bright. This also increases power consumption. In most of the cases, we need to recharge the battery in less than 3 hours.

This prototype system was designed so that it could not access the hospital PACS database directly. In the idea case, the server site can be designed to access the PACS system of the Hospital.

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