

DEVELOPMENT OF A TELEMEDICINE IMAGE PROCESSING AND TRANSFERRING SYSTEM OVER A WIRELESS COMPUTER NETWORK

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Abstract. *Purpose: To develop a telemedicine network for effective wireless interchange of medical image data in the hospital. Material and Methods: The system comprised a Dicom Server (Pentium IV, 3 MHz), 3 Clients (2 Pentium IV at 2.6 MHz, 1 Laptop Pentium III at 1MHz, 1 PDA 400 MHz), all connected over a Wireless Local Area Network. Client requests were hosted by the Server that mainly stored and processed medical data. A sockets-based communication algorithm was developed in JAVA for transferring images between the server, the clients and PDA. Transfer times for 20 microscopy images (768x576x8 bit) in bmp and lossless jpeg format were recorded. Additionally, software for the display and manipulation of images on the PC's and PDA was developed in Java. Results: Transfer times per bmp and jpeg images were about 6 and 1 seconds respectively, rendering the request and reception of an image by a client (PC, Laptop or PDA) efficient and, thus, possible for application in the clinical environment of a hospital. Conclusion: The proposed wireless network topology provides means for effective transfer of processed medical data (images), giving the physicians the flexibility to review any kind of patient data on a portable PDA.*

1 INTRODUCTION

The development of technologies and of telecommunication systems has brought exponential growth in Medical community ^[1]. Nowadays most of modern hospitals conform to the technological development and offer to the medical staff the most progressive, integrity material and technical equipment.

The development of telemedicine or 'medicine at a distance' ^[2] played crucial role in that huge technological step. The increased usage of networks technology assures not only the healthcare delivery ^[2], but also the interconnection and transfer of medical data between hospitals located at different geographical regions either through a wireless or a satellite network ^[3] installed in hospitals. In addition, special interest appeared on those applications of telemedicine that ensure the most secure electronic transfer of medical data and medical services from distance based on the most advanced telecommunication and information technologies ^[2, 3].

Plenty of techniques have been developed for the transfer of medical images by using either wired or wireless networks ^[3]. The medical data are transferred via a variety of modalities including phone, fax, interactive video, Web-based multimedia e-mail and World Wide Web technologies ^[2, 4, 5]. Most of them are based on accessible and cheap network infrastructures such as TCP/IP (Transmission Control Protocol/Internet Protocol) ^[3, 6, 7] for both LAN (Local Area Network) and WLAN (Wireless Local Area Network) ^[6]. In addition, a variety of different communication protocols has been applied in order to assure medical data transfer. Cable modems, ISDN (Integrated Services Digital Network) ^[8], and B-ISDN (Broadband-Integrated Services Digital Network) ^[9] are mostly used to connect telemedicine systems ^[6] for applications which require higher bit rates and ADSL (Asymmetric Digital Subscriber Line) ^[10]. Telemedicine applications have also been developed by using wireless technologies such as a GSM (Global System for Mobile Communication) for mobile

communication networks [3, 11].

In the current approach, a telemedicine image processing and transferring system was developed based on a JAVA communication algorithm in order to facilitate interconnection into hospital departments and provide fast and reliable diagnosis by physicists.

2 MATERIAL AND METHODS

The telemedicine system network was developed in MIPA (Medical Image Processing and Analysis) Lab that is a part of the Medical Physics Laboratory, University of Patras, Greece. The system (see figure 1) comprised a DICOM Server (Pentium IV, 3MHz) which mainly stored and forwarded medical data according to doctors' requests and four different types of workstations (2 Pentium IV at 2.6 MHz, 1 Laptop Pentium III at 1 MHz and 1 PDA (Personal Digital Assistance) 400 MHz) interconnected via a WLAN. Wireless communication between the DICOM Server and the clients was provided using an access point and wireless network cards. The Wireless Access Point (WAP) supported 802.11g and was backward-compatible with 802.11b wireless clients and the PDA of the network. The WAP provided access to the network medical resources at speeds up to 54 Mbps for 802.11g users and up to 11 Mbps for 802.11b users, at distances up to 100 meters (328 feet). The Wireless Network Cards were based on 802.11g technology and provided wireless file transfers and downloads with speeds nearly five times faster than the current Wi-Fi (IEEE 802.11b standard). The specifications of the PDA were the following: HP iPaq RX-3715 with integrated 802.11b Wi-Fi support. The operating system was the Microsoft Pocket PC 2003.

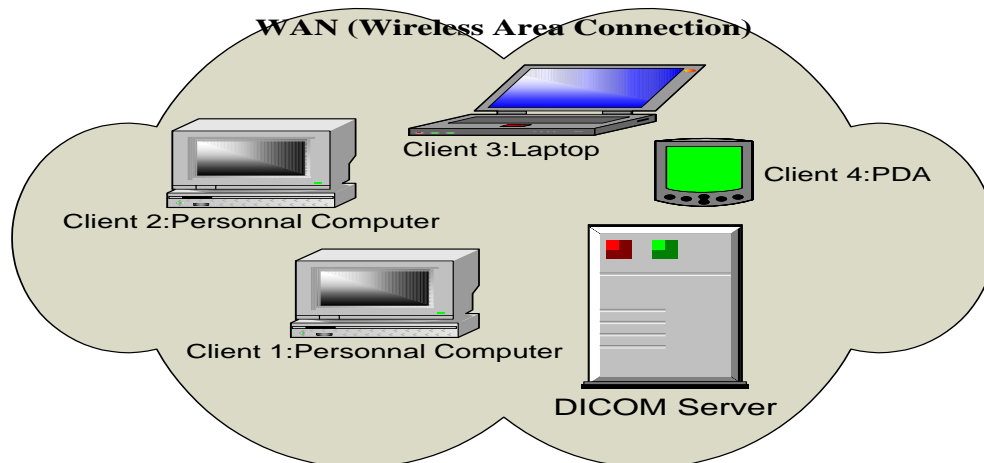


Figure 1. Schematic illustration of the developed telemedicine application over a Wireless Computer Network

To establish the medical data transfer between the DICOM Server and the clients, a socket-based communication algorithm was developed in JAVA. This algorithm allowed the TCP connection between two hosts and performed five basic operations: Connect to the remote machine, listen for requests, send and receive data, close the connection. To avoid any delay in the transmission speed for large-volume image data over the Local Area Network, data compression methods have been used [12]. To enable image-processing tasks on both the PDA and the remaining 3 clients, a custom made in C software [13] was provided that enabled displaying and manipulating the retrieved data. This application included basic image processing tasks, such as windowing techniques and histogram equalization operations and more advanced operations such as segmentation. For the PDA, additional features were provided by using the platform proposed by [13]. The medical data that were used to test the telemedicine image processing and transferring system were 20 microscopy images (768x576x8 bit) of both bmp and lossless jpeg format.

3 RESULTS AND DISCUSSION

In figure 1a, the application of an image-processing task (gray scale transformation and simple window processing) has been applied to a microscopy image of thyroid nodules. The physician can rapidly retrieve the image from the DICOM Server in transferring times about 6 seconds for BMP formats and 1 second for JPEG formats. Image size is 768x576x8 bit. Images can be manipulated, among other functions, for zooming (see

figure 2), ROI (region of interest) selection, rotating, stretching, inverting colors, cropping, saving and archiving.

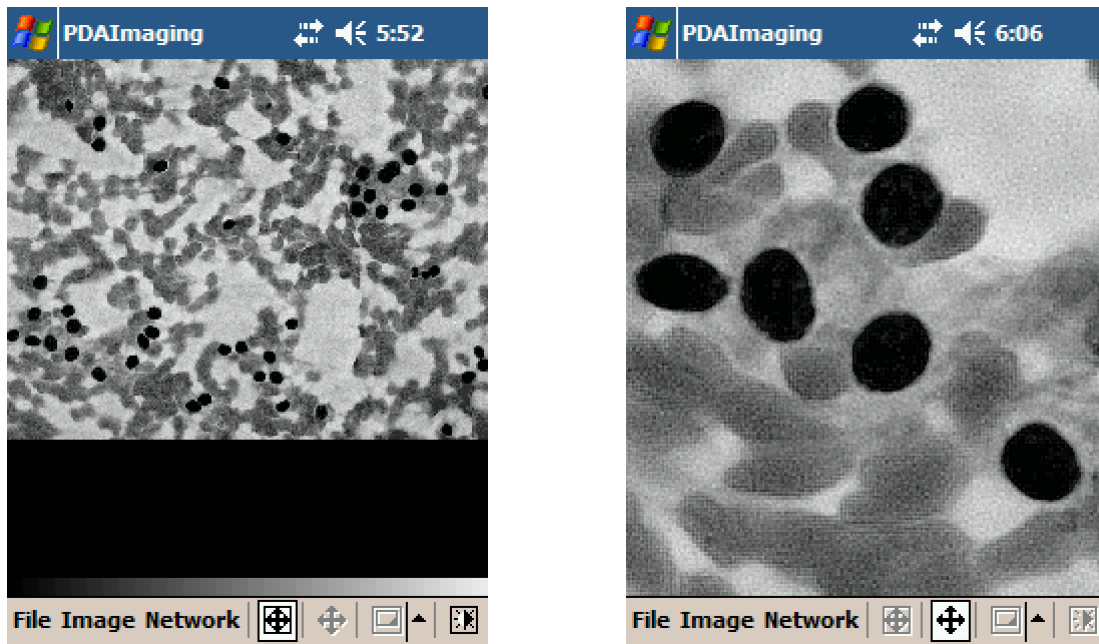
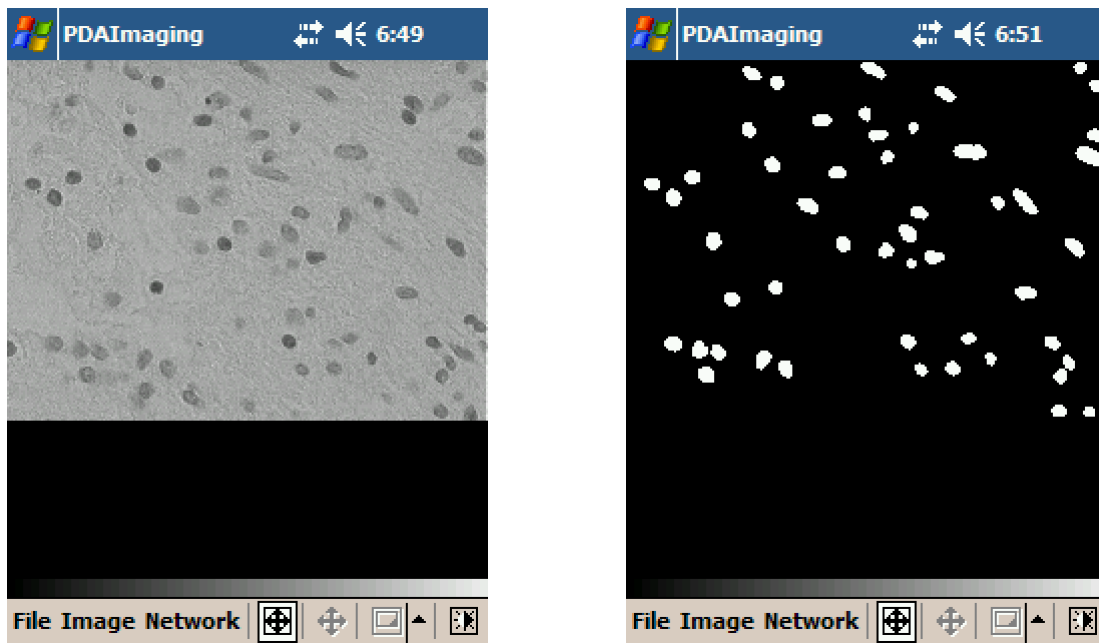


Figure 1. Retrieving, displaying and manipulating with the PDA a microscopy image of thyroid nodules

More sophisticated-operations have also been developed such as automated segmentation of nuclei, for facilitating the quantification of a variety of parameters regarding DNA content and chromatin distribution^[14] (see figure 2a-2c). In this way, physicians may rapidly interchange data through the WLAN using the PDA and consult each other to reduce sources of inter-observer reproducibility.



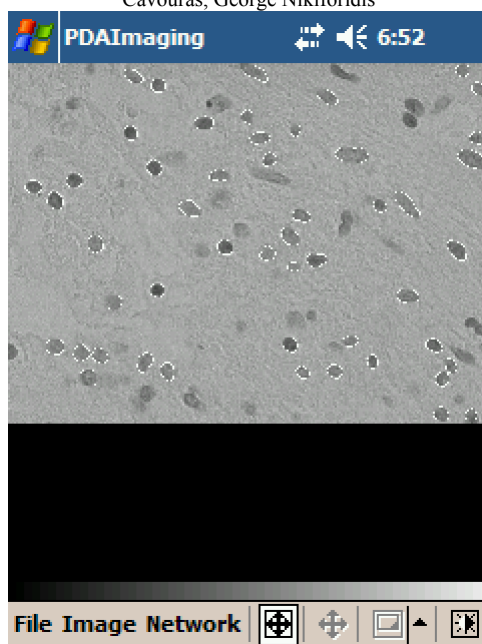


Figure 2. Display of nuclei segmentation results on the PDA: (a) Original image, (b) Binary image localizing nuclei regions, (c) Final segmented image

The developed telemedicine system enabled fast transfer of medical images anywhere into the hospital through a WLAN. Moreover, the network provided the doctors the capability to perform medical diagnosis and inter-consulting on a remote location within the hospital. The most important advantage of the applied system was the WLAN topology, which was set up with cheap equipment and offered low cost in any case of future extension. From the user's point of view, the system was easy to install, to use and to manipulate. Another advantage was that there is no need to drill holes or run Ethernet cabling to set up the network.

The proposed wireless network topology provides means for effective transfer of processed medical data (images), giving the physicians the flexibility to review any kind of patient data on a portable PDA. In addition, the system ensured transfer, manipulation and efficient interconnection of medical information among the physicists into hospital.

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