Infusing Image Processing Capabilities into an RFID-Based Personal Mobile Medical Assistant

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Abstract. The technological fusion of modern handheld devices, like Personal Digital Assistants (PDAs), wireless networking, and Radio Frequency Identification (RFID) technology, is considered capable of providing the solution to the healthcare community's increasing need to enhance patient safety and reduce medication-dispensing errors by rapid and precise delivery of medical information within an all-wireless digital hospital environment. Therefore, the aim of the current study is to propose a wireless solution that utilizes RFID technology to enable physicians and healthcare professionals to automatically identify patients and easily access their medical information through PDAs, remotely. The developed PDA-based application is capable to identify each patient's RFID tag, retrieve his/her medical data (images, bio-signals, reports, pharmaceutical treatment etc.) and display them by means of a user friendly graphical interface that suites the needs of the healthcare professional. Additionally, the application is further enhanced by incorporating advanced image processing capabilities to improve the diagnostic potential of medical images.

Keywords: PDA, RFID, Medical Assistant.

1 Introduction

According to the 1999 Institute of Medicine report, entitled "To Err Is Human: Building a Safer Health System", medical errors constitute one of the major threats in

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modern healthcare application resulting in 44.000 to 98.000 deaths in America alone [1]. In order to conceive the magnitude of the imposed threat, the aforementioned report states that deaths due to medical errors in 1998 exceeded the number of deaths attributed to motor vehicle accidents (43.458), breast cancer (42.297), and even AIDS (16.516). What's more, total annual costs associated with medical errors resulting in injury are estimated to be between 17 and 29 billion dollars.

Although, a couple decades ago, the major cause of medical errors was misbelieved to be inadequate training, or even negligence on the part of the healthcare professionals, recent studies have proven that the predominant cause of medical errors is the lack of detailed and timely information concerning the patient. Such information includes patient’s medical history and existing conditions, results of clinical tests and examinations, medical images, allergies, and current prescriptions [1-3].

Millions of people suffer from medical conditions that should be made known to healthcare practitioners prior to treatment. Doctors and nurses can not provide optimal care without sufficient knowledge of a patient’s medical history. Without access to vital patient information, healthcare professionals are prone either to delay treatment or rely on erroneous or deficient data [3].

Unfortunately, timely access to this information is in most of the cases not practical or even unfeasible, especially in emergency situations [3]. The main reason of this deficiency it that patient medical records are maintained, traditionally, in paper-based format at the offices of individual healthcare providers.

The initial step towards the solution of this problem was made with the growth of electronic medical record (EMR) systems over the past decades. Furthermore, the increased use of mobile devices, Personal Digital Assistants (PDAs), and wireless devices in general, during the past few years, has metamorphosed the way we perceive things around us and has had a radical impact on our working environment. The healthcare sector, where the need for precise and rapid delivery of information is of vital importance, could not remain unaffected by these developments. Therefore, the use of portable PDAs along with wireless LANs can satisfy the need of healthcare professionals for remote access to information.

Currently, the small size and weight of PDA devices provide tremendous convenience and portability. Additionally, with the rapid evolution of electronic technology, PDAs are now capable of accomplishing more challenging tasks, such as reproduction of video sequences and processing of static high quality medical images [4]. Moreover, the technological fusion of modern PDA handheld devices, wireless networking, and RFID technology, is considered capable of providing the solution to the healthcare community’s increasing need to enhance patient safety and reduce medication-dispensing errors by rapid and precise delivery of medical information within an all-wireless digital hospital environment.

Hence, in the current study, a previously proposed wireless solution [5] that utilizes RFID technology to enable physicians and healthcare professionals to automatically identify patients and easily access their medical information through PDAs, remotely, is further enhanced by incorporating advanced image processing capabilities in order to improve the diagnostic potential of the system.

2 Methods

2.1 System Design and Implementation

The hardware platform selected for the final prototype of this project was the Qtec 9000. The device features a 520 MHz Intel Bulverde Processor (ARM compatible), 64 MB SDRAM, 128 MB Flash ROM, a Secure Digital Card expansion slot for optionally adding extended memory capabilities and a 3.6" / 89-millimetre diagonal 640x480 64-bit color transflective TFT-LCD with backlight LEDs that supports both landscape and portrait mode. Furthermore, the specific model incorporates a full QWERTY keyboard. It also offers WiFi connectivity through its integrated IEEE 802.11b compliant wireless network card. Bluetooth and IrDA connectivity are also supported. Finally, regarding the operating system, Qtek 9000 arrives with Microsoft Windows Mobile 5.0 preloaded.

In order to add RFID capabilities to the PDA, Wireless Dynamics' SDiD 1020 RFID reader card was utilized. The particular card reads and writes to all ISO 15693, ISO 14443A/B and many proprietary 13.56Mhz RFID tags being used or deployed for asset tracking, access control, process control and healthcare/medical/pharmaceutical applications [6]. Moreover, due to its battery friendly design, the RFID card draws only a few milliamps (11 mA) of current in standby mode, extending the battery life of the PDA. The RFID transponders-tags employed in this study were a member of class 0 (passive, read only), operated at the frequency of 13.56 MHz and were mounted on the patient's wrist bracelet. This choice was based on the fact that RFID systems using this frequency have a large user base and are supported by many RFID manufacturers such as Sony and Phillips [7].

A PDA-based application was developed in C# (C sharp) programming language taking full advantage of the .NET Compact Framework. The software packages used during the implementation phase include: (a) Microsoft Visual C# 2005 Express Edition (Integrated Development Environment), (b) Microsoft .NET Compact Framework SDK (Software Development Kit) 2.0 (c) Microsoft Pocket PC SDK 2003.

It should be noted that the application was developed on a typical desktop PC (Intel Pentium 4 / 1.8GHz with 1GB RAM) running Microsoft Windows XP, while for database management Microsoft SQL Server 2005 Express Edition was employed. An overview of the proposed system is illustrated in Fig. 1.

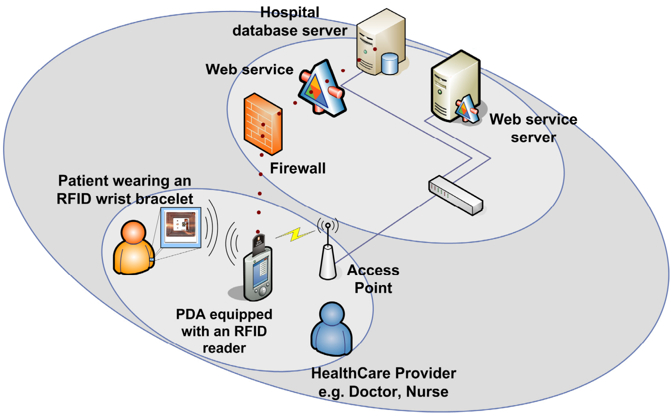

Fig. 1. An overview of the proposed system

2.2 System Functionality

The aforementioned application is capable to control the RFID reader connected to the PDA, and therefore to read each patient's RFID tag (interrogation phase). During this interrogation phase, which lasts only less than a second, the RFID reader should be within a couple of centimetres away from the patient's tag (Fig. 2). Successful completion of this phase results in the acquisition of the tag's unique ID, which is an 8 byte stream.

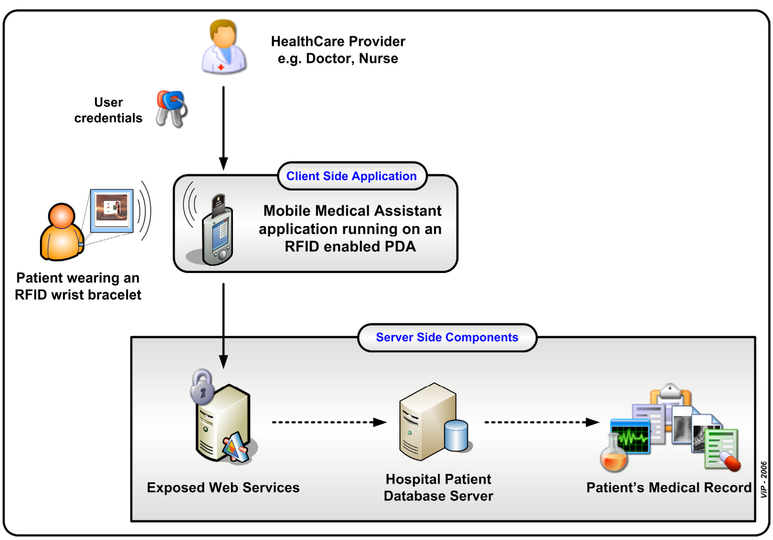

Fig. 2. A typical use case scenario involving all key components of the proposed system

Following the correct identification of the patient through his/her RFID tag, the developed application can query the hospital's database and retrieve his/her medical data comprising medical history, past conditions, medical images, vital signs (temperature, pressure, pulse, etc) presented in graphical view, clinical reports, current pharmaceutical treatment etc.

All the retrieved information is then displayed by means of a user-friendly graphical interface that suits the needs of the healthcare professional. In order to accomplish this, special effort was made during the design of the graphical user interface (GUI), so that the application provides for easy information navigation. Additionally, information is categorized into logically related units for more effective consumption. Moreover, once the patient's medical record has been retrieved from the database, the healthcare professional can easily update it with the latest information.

As far as image viewing is considered, the developed application can be used to download and display a wide variety of images, whether they are color (RGB) or grayscale of the following formats: DICOM, BMP, JPG, GIF, PNG and TIFF. Additionally, it can open practically any size of image, but the maximum visible resolution is limited to 640 x 480 pixels. Larger images can also be viewed using a special 'Shrink to Fit' function that employs the appropriate zoom factor, so that the original image fits in a 640 x 480 frame. The user has also the ability to scroll the image (using the stylus) in its original size. This function is called 'Tap & Scroll'. Zooming and rotation, in angles multiples of 90°, are also featured. Additionally, standard mirroring and flipping image transformations are supported. Finally, the information contained in the DICOM header can be accessed to obtain valuable information regarding the displayed image.

The application can process the loaded images using special-purpose algorithms to enhance image quality. One of the most commonly used image enhancement method is the "windowing correction" technique [8], which is used in the application in two ways: (a) by window-width and window-level adjustment using two slider bars and (b) by stylus movement, for adjusting image brightness and contrast. In addition, the application uses image enhancement techniques for (a) contrast enhancement by means of histogram modification (Cumulative Density Function based Histogram Equalization), (b) typical 2-dimensional convolution filtering, including smoothing, laplacian, high emphasis and unsharp, and (c) adaptive median filtering for de-speckling of ultrasound images.

The whole application was designed in a robust and compact way, in order to utilize the PDA's CPU and memory resources as optimally as possible.

Web services technology was employed in order to accommodate every transaction between the remote medical database and the client application running on the handheld device. Hence, the main role of the implemented web service is to act as an abstraction layer operating above the database, and return data to the client application. Furthermore, the task of user authentication is also assigned to the web service. All web functions were described (name, return types and input parameters) using the WSDL (Web Services Description Language) [9].

Finally, regarding security, Microsoft's implementation of UsernameToken was used to perform direct authentication at the message layer. This process can be summarised as follows. The application passes the credentials to the web service as part of a secure message exchange. A password is sent in the message as plaintext, which is data in its unencrypted or decrypted form. The Web service, then, decrypts the message, validates the credentials, verifies the message signature, and then sends an encrypted response back to the application [10].

3 Results and Discussion

The solution was evaluated by an experienced healthcare professional in a real healthcare environment (EUROMEDICA Medical Center) in terms of mobility, usability, stability, and performance, and was found to be a useful modality for healthcare providers that could further enhance their diagnostic capabilities by providing timely access to patient's information. Moreover the use of RFID tags guaranteed correct patient identification.

The application's response times fell within acceptable limits depending on the type and volume of data exchanged. The use of XML web services for access to the database promoted the system's interoperability, at the cost of slightly higher response times, caused by an extra overhead in data exchange. The use of new generation wireless network technologies, such as IEEE 802.11g (55Mbps) instead of 802.11b (11Mbps), can further improve the response times.

Furthermore, both static image viewing and graphical illustration of patient's vital signs were evaluated as adequate by the expert physician. Full DICOM transferring and decoding support for image files rendered the application plausible for a modern hospital environment. Most of the integrated image filtering algorithms exhibited acceptable performance regarding their processing times.

The application's GUI was found to be simple and intuitive, while it facilitated a pleasant and rich user experience, even to users unfamiliar with PDA-based applications.

Regarding future work, the use of active RFID tags – that support both read and write access- should be considered. Active RFID tags could be employed in order to store the patient's own medical record.

Because it is considered crucial for enhancing the user experience and enabling the effective consumption of information content, design of an improved GUI is therefore among the major issues that need further study and effort.

Another idea for future work could be the implementation of more advanced image enhancement algorithms that could be integrated in the application.

Finally, security of the proposed system should be further enhanced. Hence, more reliable authentication methods and up-to-date, powerful encryption algorithms could be adopted in order to fortify patients' sensitive medical data against tampering or interception.

4 Conclusion

By exploiting state-of-art RFID technology, a PDA-based application was designed for identification and accessing of each patient's medical record and through evaluation was proved to be plausible for application in a modern hospital environment. In addition, integration of image processing algorithms was a valuable feature that could potentially upgrade the role of the proposed system from a tool providing access to essential patient information into an important preliminary diagnostic asset.

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