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A Novel Image Capture System for Use in Telehealth Applications

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Abstract— **A novel image capture and retrieval system has been developed for use in a range of telehealth applications in the home and in residential care facilities. The system is based around the JPEG 2000 standard and uses the PTP protocol for image capture from any high resolution digital camera and the Kakadu suite of JPEG2000 utilities to serve the collected images via a proxy server over any available communication channel from telephone lines to broadband services. When coupled with an image processing system such as the AMWIS system for pressure wound management, the system provides a high level of clinical functionality suitable for a wide range of telemedicine applications in rural and remote sites.**

I. INTRODUCTION

THIS paper is concerned with the development of a low-cost imaging system for use in the UNSW home telecare system or Telemedcare. The imaging system allows a patient at a private home or nursing care facility to capture an image with a consumer digital camera, and deliver the image efficiently over the Internet to the medical practitioner in charge of the patient. The emphasis is on the acquisition and delivery of images from patient to practitioner. The system is thus potentially a good complement to a dedicated wound imaging system like the AMWIS system being employed in several sites around Australia [18]. The AMWIS system allows a health officer to accurately measure the area of a wound and produce a comprehensive wound record to be presented to a specialist. However, acquiring and inserting an image into the system has to be performed manually, and transmission of an image is done via email, which may be inefficient for large images.

II. TELEMEDCARE

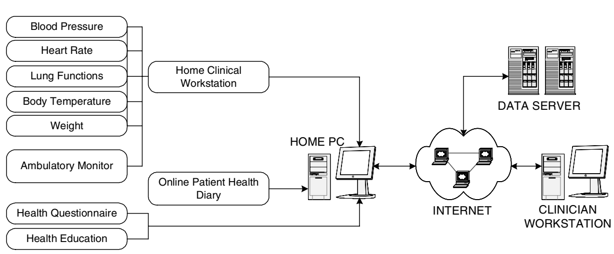

Figure 1-Diagram of Telemedcare System

The in-house home telecare system, or Telemedcare [7], [8], [9], provides a home patient with self-administered functional health status measures in the form of questionnaires, remote monitoring of parameters of daily changes to patient status, and clinical measuring devices. Acquisition of biomedical data or questionnaire responses is carried out via the Internet. Data is stored in a database and later analyzed for longitudinal trends. This data is available on request to the client (usually a general practitioner or GP) via a web browser.

The patient is provided with a clinical workstation. It is modular and includes:

1) ECG, blood pressure, spirometer, blood oximetry, sphygmomanometer.
2) Low power RF interface to ambulatory patient worn device for telephone voice connection on emergency button press & triaxial accelerometer.
3) Accurate patient weight and temperature.
4) Ambient temperature, light and humidity.

Based on case studies and clinical trials, the Telemedcare system has been shown to be functional and effective. It has been deployed in actual home settings and is a useful tool for the management of chronic illnesses like congestive heart failure and chronic obstructive pulmonary disease [8]. For home telecare, the minimization of cost is important, and the home telecare system achieves this by emphasizing modularity in its design, so that the modules required can be tailored to suit individual patients' needs. The patient user interfaces are designed to be simple and intuitive, so that users of the system need not have had any prior experience using computers.

III. IMAGING MODALITIES FOR TELECARE SYSTEMS

A. *Common modalities*

The imaging modalities that are most commonly used in telemedicine are the `store-and-forward system' modality [14], [15], [17], where images are saved locally, then forwarded by email to the recipient, and the real-time video/web conferencing modality [10], [14], [17]. For both modalities, image transmission over a network with limited bandwidth hampers their effectiveness. In the former, the GP may need to wait for a long time for large images to arrive. In the latter, the conferencing session may experience high delay and latency. In addition, conferencing systems tend to incur higher implementation costs.

B. *JPEG2000 and Progressive Transmission*

Telemedcare does not currently have any facility for imaging acquisition and analysis. This project attempts to utilize progressive image transmission as an imaging modality for Telemedcare. We use the JPEG2000 imaging standard which allows for efficient compression, scalability

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and codestream flexibility amongst its many benefits [2], [5]. The standard allows progressive transmission of compressed image based on precinct, component, resolution or layer. The standard also defines the JPEG2000 interactive protocol (JPIP), which is based on HTTP, for efficient serving of images over data networks [1], [3], [6].

With JPIP we can efficiently browse (or serve) large images remotely, and with a judicious choice of progression we can browse images with good quality even over low datarate networks. For instance by encoding an image with a number of quality layers and browsing this image remotely, a low quality or grainy representation of the image can firstly be brought to view. As additional data is sent the image quality is successively improved. In addition, a region of interest of the image may be selected such that only that region is improved in quality. Quality progression allows the user to have a `view' of the image even at low quality instead of waiting for the image to load from top to bottom as is conventionally done, and region-of-interest selection allows the user to enhance a particular location of the image while ignoring its surroundings which may be deemed to be unimportant.

C. *Use of COTs imaging devices in telemedicine*

The use of digital cameras in telemedicine is not new. In [16], such cameras used in the context of teledermatology were found to provide clinicians with high-quality images suitable for diagnosis, with outcomes comparing well with in-person consultations.

IV. SYSTEM OVERVIEW

Digital cameras are commonly available with a proliferation of different models from many vendors, but we need to interface with the camera firmware to develop custom software for the system. To achieve this, we use an open standard called Picture Transfer Protocol (PTP) or formally known as PIMA/ISO 15740 [13]. PTP defines a set of containers and data formats, standard imaging referencing behaviour, operations, responses, events, device properties and datasets for transferring data to and from a digital still photography device and devices such as computers and printers. PTP also defines optional operations and formats, and mechanisms for extending the protocol by individual vendors. This imaging protocol removes the need for camera-specific drivers. PTP supports common device controls like image capture and image download, providing us with flexibility in application development. The PTP standard is also transport-independent, with details needed to use PTP with USB provided with the standard. The use of PTP is primarily advantageous because it eliminates the need to use proprietary protocols for different device vendors to communicate with the camera firmware. All major camera vendors have provided support for PTP in most (if not all) of their products since 2002 [12]. However we are still subject to the limitation of the subset of PTP operations and properties that manufacturers choose to support in their camera firmware.

The most prevalent image format in use with imaging devices is JPEG, and thus we will be working primarily with this format. In order to exploit the benefits of JPEG2000, the image capture program incorporates means for converting image file formats supported by digital cameras to JPEG2000. Commonly used web browsers like Netscape, Firefox and Internet Explorer have in-built capabilities to render and display JPEG images. During the transcoding operation, we also use the JPEG converter to produce a low-resolution thumbnail of the original image captured by the imaging device. We can thus take advantage of the browser capabilities to easily present previews of the images stored in the central database to the client.

The Telemedcare system uses a hybrid system for storage of biomedical signals acquired from the clinical workstation. In a hybrid system, a shared-file database collects data locally, then periodically synchronizes this data with the central database server (an umbrella term for processing, broker and database servers) through the Internet or a local area network. In this way the system is able to utilize network resources more efficiently and support multiple users [7]. The central database itself stores the clinical data, including ECG and blood pressure readings.

The use of JPEG thumbnails allows the preview of many images at once with only a small cost in bandwidth. There is thus no need to send the full JPEG2000 image if it is not required. After synchronization the processing server will open a connection to the database server, process the image records and store the main JPEG2000 images in a separate directory on the processing server, while the thumbnails will be reinserted into a separate table as part of the database server. Other metadata related to the images can be inserted together with the thumbnails as part of a comprehensive collection of information related to the patient images generated.

Clients may be served by a proxy server instead of the central database, which behaves as the ultimate server for all the images collected from the patients. The client application establishes a stateful JPIP session with the server. The proxy is JPIP-compliant, i.e. it accepts JPIP requests from a client and issues its own JPIP requests to the ultimate server. The proxy caches images, which it requests, which it can then use to satisfy subsequent requests for the same images, possibly from different clients. The proxy can cache and serve incomplete images. We adhere to a JPIP principle that the server may serve image data in any order it pleases, thus the proxy just serves whatever is present in the image cache. The proxy server however is deficient in the following senses:

1) the proxy is filled with image data only when prompted by client request.
2) it only supports HTTP transport although JPIP provides for HTTP-TCP as well
3) it has only been tested with meta information necessary for opening and displaying the JP2 file format.

We use open source software for PTP and USB available via [11] and [12]. To work with JPEG2000, we use the Kakadu Software [4]. Kakadu is a comprehensive, optimized and fully compliant software for developing JPEG2000 applications. Kakadu is not freely available, but a license can be obtained at an affordable cost, and the license grants the user with unlimited upgrades and compilations.

Each of the proxy and client applications uses or is based on Kakadu. For the patient-side camera capture utility, we use the open source LibUSB and LibPTP libraries and a LibUSB wrapper to allow custom USB communication. If the platform is non-Windows XP an additional open-source generic digital camera driver must also be installed in order to talk to the imaging device. We use Cold Fusion markup and SQL for database queries as noted above. The applications themselves have been executed on Windows 2000 and XP platforms. A precompiled Kakadu DLL is required to run the programs.

There are no special hardware requirements for running the applications, except for a personal computer with dial-up or broadband internet access, as well as a digital camera for image capture which supports PTP.

V. SYSTEM OPERATION

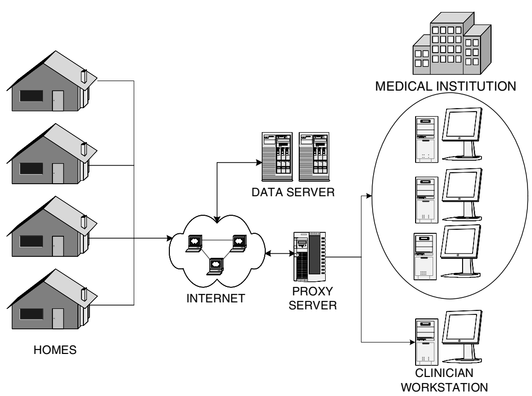

Figure 2 - Structure of Imaging System

A. *Home patient-side description*

At the patient side, the home clinical workstation presents a simple user interface to the patient. The patient captures an image using a digital camera connected to the workstation. At present the transport medium used is USB. The image is captured as JPEG but converted into JPEG2000. A JPEG thumbnail is created simultaneously. The image is encoded by Multipurpose Internet Mail Extensions (MIME) encoding and sent as XML to the Telemedcare database, along with the thumbnail. The use of MIME and XML is to conform with the existing data encapsulation paradigm in use in Telemedcare. The thumbnail is stored in the database along with other clinical data produced by the home workstation. The actual image is stored separate from the main database, without modifications.

The image acquisition software is set up by default for macro or close-up shots. Advanced users may access a menu and adjust parameters to suit their preferences, including flash, white balance, exposure, zoom, aperture and shutter speed settings, image quality and file sizes. Available parameters are determined at run-time by querying the camera, as not all parameters may be supported by every camera

The existing Home Desktop software infrastructure is used to perform synchronization with the central database server and transmit the image data over the network.

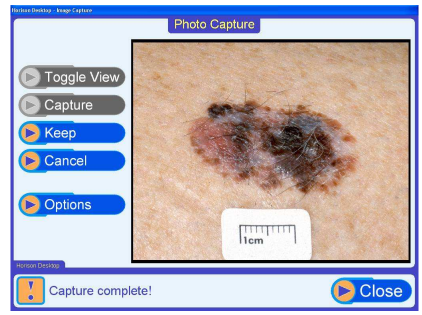

Figure 3 - Image Capture User Interface

B. *Client-side description*

At the client or GP workstation, the client browses images available on the central database through a web interface. The database returns the thumbnail previews for the current patient. When the client clicks on the preview, an application is launched which allows interactive browsing of the requested image via JPIP. The client may be served by a proxy cache, but this would be transparent to the client.

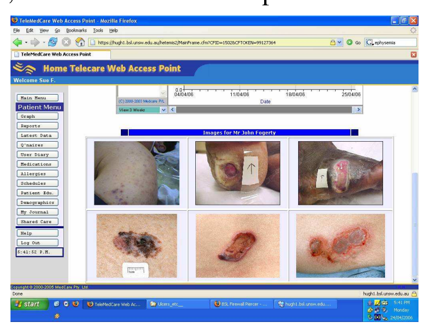

Figure 4 - Client-side Interface

C. *Database description*

During episodic synchronization with the patient workstations, the central database server accepts incoming "suitcase" files containing the biomedical patient data and images, together with the thumbnail previews, and inserts them into a table. All newly-accepted data files will be stored as records in this table, including our image data. The record which appears in the table remains the compressed data encased in XML format. So, we need to reverse all the processes which were involved in preparing the image data for transmission on the Home Desktop side. The processing server runs a Cold Fusion server which parses the web requests from clients, and accesses the database server accordingly. The actual image requested is served by a JPIP server running separately.

D. Interactive application description

The interactive application is based on the *kdu_show* application provided with Kakadu to view JPEG2000 images. As well as able to display local or remote images within a selected region-of-interest, *kdu_show* is also able to edit optional metadata such as labels in the images, and perform simple spatial manipulations like rotate and flip.

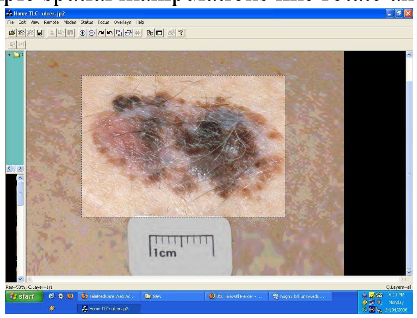

Figure 5 - Interactive application

VI. Mini-trial and Results

Sample images as shown in Figures 3-5 were taken at a number of locations and transmitted via the system to demonstrate the system's usability. A Canon Powershot Pro1 was used to acquire the images. The following settings were used for the camera: F8.0 aperture (smallest), 2"5 shutter speed, superfine image quality, large image size, macro mode, auto white balance, no flash. Aperture and shutter speed were found to be particularly important, where a combination of small aperture and slow shutter speed yielded sharpest images and maximum depth-of-field. The slow shutter speed however necessitated a steady camera while an image was shot.

Preliminary work has also been completed to link the imaging system to the Alfred Medseed Wound Imaging System V1.0 [18] which will permit a baseline health assessment, and ongoing AMWIS wound assessment for duration of wound management to assess the base-line healing rate (% change in wound size per week).

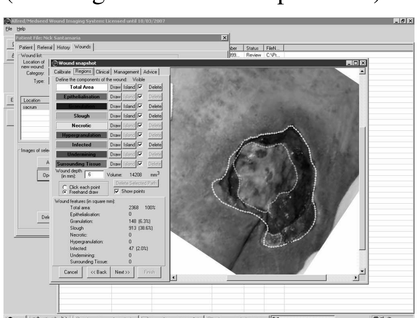

Figure 6. AMWIS analysis of wound profile

Future Work

Currently the imaging system leverages the existing infrastructure to transmit images between the Home Desktop and the central database server. This was a design decision such that the imaging system could fit into Telemedcare easily. However this link is not optimized for large data like images, and will be subject to further research. Also, we intend to establish an image indexing and retrieval system, possibly separate from the current database implementation. We plan to add two major forms of functionality to the application: simple image processing tools and the ability to annotate the images displayed using the application. Wireless LAN cameras have recently been released in the market; support for these may be added in future.

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