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MOBILE TELERADIOLOGY: ALL IMAGES EVERYWHERE

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This paper describes the ongoing work on mobile teleradiology systems in the EC-funded project MTM. The current development is based on the CHILI software architecture which provides a PACS and teleradiology infrastructure. The authors collected user requirements in a first step. Appropriate hardware has been selected based on these requirements. Dedicated software versions of CHILI have been realized on selected PDA hardware. The target of the MTM project is to use UMTS for wireless communication. A wireless local area network (WLAN, IEEE 802.11b) is currently used, as UMTS is not yet available.

We have implemented the full functionality of a regular workstation in the initial version of the software. A first evaluation found out that such a high level of functionality is both difficult to implement in a useful manner but also not really requested by medical users in an actual situation. Future software versions therefore need to focus more on usability issues and core functionality.

Keywords: Teleradiology, wireless, UMTS, mobile computing, evaluation, PACS

1. INTRODUCTION

The introduction of small and portable personal digital assistants, mobile phones, and wireless communication in general, has already changed the way we communicate with each other — not only in extreme situations but also for everyday routine communication. This change will also affect the way we communicate in our professional life.

The goal of the authors is to develop mobile teleradiology systems which are independent of stationary and cable-bound computers. This development is based on the existing commercial CHILI® (tele-) radiology workstation (Steinbeis Transferzentrum Medizinische Informatik, Heidelberg, Germany) which is the result of a joint project with the German Cancer Research Center in Heidelberg, Germany. The mobile teleradiology software will use personal digital assistants (PDAs), pen-based computers or webpads for wireless access to the medical images stored in the archive of a PACS or DICOM compatible workstations. Mobile users will be able to receive images from stationary computers, apply basic functions to the images and perform interactive teleconferences with shared (mouse) pointers and

synchronized image manipulation functions.

The consortium of the MTM project [1], funded by the commission of the European Community in the IST-Program (MTM IST 1999-11100), is developing a PDA with special capabilities, such as high speed communication using Universal Mobile Telecommunication System (UMTS) [2], possibility to send and receive audio/video, access to data such as web pages and e-mail. The PDA itself is a general tool and it will not only be used for medical purposes but also for tourist guides, distance learning etc.

To be able to build such a PDA we must know more about the performance and capabilities that users demand. For this purpose we sent out a questionnaire to medical users (including medical imaging departments) to find out more about hardware requirements of the PDA and application specific requirements.

2. USER REQUIREMENTS

A questionnaire was distributed to physicians in Spain and Germany to find out the specific requirements for a wireless teleradiology application [7]. All physicians work at imaging departments, most of them at radiology departments. 40 physicians filled out the questionnaire. The user group represents a total of more than 400 years of expertise in their respective fields. The most important results were:

- Image size: Minimal image size is 256^2. Users indicate a typical range of 256^2 up to 512^2 as being very frequent. 12 bit is common. Uncompressed that corresponds to 524 kB per image (12 bits are stored as 16).
- Display: Color display is not required by all. Many gray levels are wanted. Users definitely want the largest display possible, and prefer the larger display in favor of reducing weight. It can be noticed that, in comparison to what's available on the market, users have high expectations on display size and resolution.
- Level/Window: is mandatory. Should perform in seconds or less.
- Compression: Lossy image compression is tolerated, even with visible effects.
- Communication: A 12-bit image of size 512^2 should transmit within 10 seconds, never more than 20 seconds. Users emphasize communication performance, together with display properties, to the extreme. In fact they do not expect the MTM to perform worse than a regular computer in these aspects.
- Input: Pen is preferred. Maybe keyboard for longer types of input.
- Development: Open solutions are emphasized. Users indicate they themselves would like to develop applications which should also run on regular computers.
- Application Scenarios: *"Neuro surgical emergency consultation"* is regarded as the most important application area followed by *"Increased access to senior staff"* as second. Further proposed application scenarios are: *"Bedside access to patient data"*, *"Radiologist in contact with modality"* and *"Access to functional MR specialist"*.

3. HARDWARE

3.1. Specifications based on the user requirements

General hardware requirements have been collected from potential users in the application fields of the project. The following hardware specifications are a result of the users' requests

with regard to available technology in the market: The PDA will use a UMTS module for wireless transmission of data. High speed communication will be provided in a range from 150 Kb/s to 2 Mb/s. Loudspeaker, video camera and microphone will be incorporated. An IRDA interface will allow the exchange of data with PCs. The RAM will range from 16-64 MB. Application software can be downloaded and stored in a flash memory. The SVGA display will be a LCD color touch screen with a resolution of 240x320 pixel. Basis internet functionality will be e-mail reading/writing and browsing. The operating system is Linux. A PCMCIA slot allows to use extension cards for LAN or wireless LAN communications, USB or microdisks.

3.2. Integration of an available product

It is not possible to develop a complete PDA within an EU project lasting only two years. The strategy of the project is to use an existing product, and to extend it by specific additions for the project purpose. The iPAQ pocket PC H3600 (Compaq Computer Corporation) has been selected to be the core of the MTM hardware [8]. Some basic features are: 206 MHz Intel Strong Arm processor, TFT LCD 4096 colors, 16 shades of gray, touch screen with resolution of 240x320 pixel (2.26x3.02 inches), 16 MB RAM, 16 MB Flash ROM. It is delivered with the Windows® Powered PocketPC operating system. But several Linux distributions are available as well, even by Compaq. We are running it under Linux as the users requested an open system explicitly. This device can be equipped with expansion packs for additional hardware options, like PC card slots. All missing hardware features for the MTM PDA will be integrated into a new expansion pack, such as UMTS module, video camera, and microphone with noise reduction.

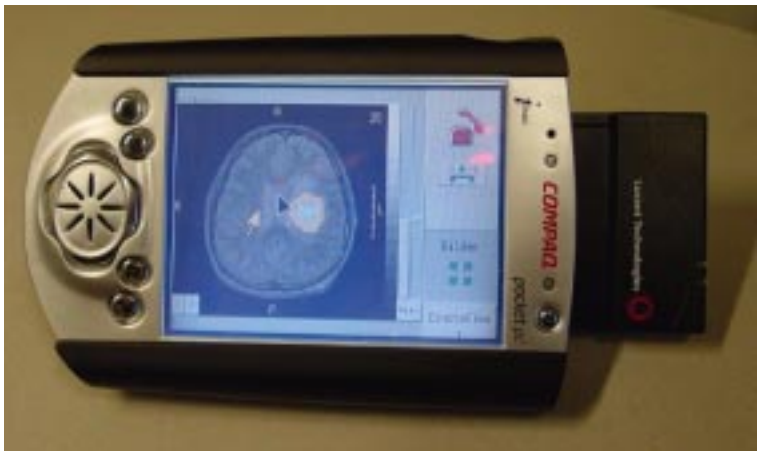

Fig. 1. The mobile CHILI prototype in a teleconference (see the two cursors) on the iPAQ H3630 with wireless ethernet card

The iPAQ H3630 with a PC card expansion pack is used for software evaluations during the project. A PC card for wireless area network based on the standard IEEE 802.11b is used to implement a wireless network and to simulate the UMTS network connection.

4. A FIRST SOFTWARE PROTOTYPE

A first prototype of the mobile teleradiology application has been developed by modifications to the existing CHILI viewer [5]. The application could be compiled on the target machine (under Linux) without major problems. The port took less than a day.

Modifications are necessary due to a number of limitations of the PDA hardware. The GUI had to be changed dramatically as the PDA has a smaller display (320x240 pixel instead of

1280x1024). Several work tasks of the viewer could be removed as the mobile application does not need the full functionality of a workstation. Just the image viewing work tasks and a configuration work task is needed for the first prototype. The database browser will be activated in the next version.

PDAs do not have a mouse and mouse buttons. The “tap&hold” method (as seen on Windows CE) has been implemented as a replacement for the missing right mouse button. This means that the user has to tap on the display and hold the pen still until a menu pops up. Then the user can select a menu entry with the pen.

A stationary CHILI server can submit DICOM images to the mobile viewer running on the iPAQ. The mobile user hears an alarm and can then perform some basic functions on the received images. Available functions are: interactive change of level/window, level/window presets, zooming, panning, magnifying glass, measuring of length, area, ROI, drawing, navigation in the image data set.

The first mode of operation is called “image pager”. Additionally, the user can hold a teleconference with a user at the server. Images at both sides are synchronized during the teleconference. Both (mouse) cursors are visible in the conference. Both users can point out details in the images.

5. USER EVALUATION OF THE FIRST PROTOTYPE

5.1. Introduction

During February and March 2001 an evaluation of the current CHILI prototype was carried out in cooperation with three radiology departments at the German Cancer Research Center (Heidelberg, Germany), Clinica Femenia (Palma, Spain) and Sanatorio de Nuestra Seniora del Rosario (Madrid, Spain). This section describes the findings we gained.

5.2. Setup

The setup consisted of several hard- and software components which were installed at the departments where the evaluation took place:

- A CHILI workstation with DICOM server installed on a Linux PC (Heidelberg) or on a SGI O2 running IRIX 6.5 (Palma, Madrid). It was connected to several modalities (CT, MR, US) and PACS workstations (Advantage Windows, Radworks).
- A Wireless LAN (IEEE 802.11b) Access Point (ORiNOCO AP-1000).
- Mobile CHILI application on a Compaq iPAQ running Linux equipped with a PC card expansion pack and an ORiNOCO WLAN card (IEEE 802.11b).

All usage was filmed on video and the interviews were recorded on an audio tape. The tests consisted of three parts: First the interviewer demonstrated how to use the PDA with the mobile application. Then the test person tried out some tools for her-/himself. This was followed by an interview and discussion (open questions with interview guide).

5.3. Results

All interviewed radiologists use computers and medical imaging software in daily routine. They are generally open-minded towards computers and feel comfortable using them. Some test persons are already PDA users (PalmPilot).

We found out that the first version of the application is a bit too complex and un-intuitive to be used without training. Not all the functionality currently available is really needed in the

planned medical context. Some basic tools (pan/zoom, level/window with presets, pointer) would be enough: for example, pan and zoom would make the magnifying glass superfluous. Measuring functions (e.g. length) were difficult to use and some users stated they would not use these tools on a small device at all.

The “tap&hold” method (as a replacement of the right mouse button) caused some difficulties. It is a solution that is prone to errors as it is too easy to accidentally pop up the menus. The negative effects of the “tap&hold” method were apparent even when tried out by experienced Palm users.

The iPAQ’s insufficient performance made some “live” tools difficult to use. Continuous zooming or interactive level/window operations work very slowly due to a missing floating point unit (FPU) and network delays. This was not indicated by the software to the users who kept on performing new operations resulting in the application being overloaded.

The iPAQ’s size and weight were considered acceptable. The image quality was considered good enough for the desired scenarios. There was no definite opinion about the orientation (landscape or portrait). The battery lasted about 3 to 4 hours with continuous use and without power management.

5.4. Recommendations

The application’s next version should become more simple and self explaining. There should only be a few work tasks (e.g. images, database, configuration and communication) and tools (e.g. pan/zoom, level/window, l/w presets, pointer).

All functions should be accessible directly via software buttons instead of the “tap&hold” method. Hardware buttons could be used as an alternative for advanced users.

The iPAQ’s performance suggests to implement zoom and level/window using discrete steps. Three zoom levels (full screen, original, double size) would be sufficient. Level/window could be accessed via presets or by selecting a ROI according to which the image is recalculated. Overloading of the application should be indicated to the user and no further actions should be accepted during performance peaks.

The iPAQ power management should be integrated to extent the battery duration. The level of backlight should be configurable by the user or even adapted automatically (the iPAQ has a built-in light sensor).

6. CONCLUSION

The MTM consortium is working on the design and implementation of a new generation of PDAs using UMTS and wireless local area networks for communications. User requirements have been collected in questionnaires from testbed users of the project consortium. These requirements have been used to define the PDA hardware for MTM. Specific applications scenarios have been investigated in more detail to learn about the users’ needs and expectations, especially in the telemedicine field. A prototype of a mobile teleradiology system has then been built by modifications of the existing CHILI teleradiology system. This prototype has been evaluated by end users to get feedback before it is used in daily routine. The results of that evaluation gave us useful hints for improvements. Most of the problems were caused by the lack of a mouse, resp. mouse buttons, and the performance of the processor, resp. the missing floating point processor.

The overall experiences with the first prototype and the iPAQ are very positive. The iPAQ

seems to be a well suited platform for the users' needs. It was a surprise that even the quality of grayscale images (displayed with 4 bit) was sufficient in the context of the tested application scenario.

A new software version is currently under development which takes these experiences into account. Most changes have to be done at the graphical user interface. Some changes are necessary in the code of the core functions to avoid floating point operations.

Data security measures will be implemented as well in the next version. New issues in comparison to the existing CHILI software are point-to-point data encryption over the wireless network using the network hardware and protocol and, additionally, application specific encryption. Only registered network devices will be allowed to access the wireless network.

The next software version will be ready for evaluations in daily routine scenarios in June 2001.

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