

ECG in Your Hands: a Multi-Vendor ECG Viewer for Personal Digital Assistants

F Chiarugi¹, M Spanakis¹, PJ Lees¹, CE Chronaki¹, M Tsiknakis¹, SC Orphanoudakis^{1,2}

¹CMI-HTA, Institute of Computer Science, Foundation for Research and Technology - Hellas, ICS-FORTH, Heraklion, Crete, Greece

²Department of Computer Science, University of Crete, Heraklion, Crete, Greece

Abstract

In the context of HYGEIAnet, the regional health network of Crete, numerous information systems have been developed to support the management of patient related data. In all these systems the digital acquisition and storage of clinical examinations and various vital signs play a major role in the provision of continuity of care to each patient in the region through the Integrated Electronic Health Record (IEHR).

In such environment, Personal Digital Assistants (PDAs) can be of great value to doctors on the move. The long-term goal is to extend the access to e-Health and m-Health services and to the citizen's multimedia IEHR through the use of such devices. PDAs have already been used worldwide for the display and editing of textual information, while their graphic capabilities are also continuously improving. The development of new software components for the display of specific multimedia clinical information on PDAs should speed up our long-term goal.

As a first step, a multi-vendor ECG viewer for PDAs has been developed and successfully evaluated by cardiologists and general practitioners.

1. Introduction

In the context of HYGEIAnet, the regional health network of Crete, various systems have been developed, including Primary Health Care Information System, Hospital Information System, Pre-Hospital Information System, Home Care, e-Health platforms for secondary opinion provision and e-Health support to the mobile patient. In all these systems the acquisition and storage of clinical examinations and various vital signs from the patient play a major role in the provision of continuity of care to each patient in the region.

In the worldwide scenario, as healthcare costs continue to rise and available funds continue to decrease, physicians continue to search for ways to cut spending

while improving patient care. Advances in Personal Digital Assistants (PDAs) have changed the devices from electronic address books to powerful tools with wireless connectivity. PDAs have the capability of accessing the Internet, sending and receiving e-mail and text messaging, and functioning as an information repository. The healthcare industry has been quick to accept and use PDAs. Pharmaceutical companies are providing medical practitioners with portable wireless access to a wealth of medical information that can support them in their practice. The devices are also a great tool in helping physicians improve office and personal efficiency via calendaring, contact and other software. Already, 25% of US physicians use PDAs [1]. The number of applications of PDA in different health specialties, such as radiology, intensive care, nursing, etc., has grown in recent years [2-4] showing that real-time monitoring of vital signs is also feasible [5].

Thus, PDAs can provide immediate and ubiquitous access to the patient's Integrated Electronic Health Care Record. Such a capability can be further enhanced if the device is also able to display graphical information related to clinical examinations. In fact, the graphic capabilities of these devices are also continuously improving.

These considerations were of primary importance in our decision to start the development of components for the viewing of clinical examination on PDAs.

In HYGEIAnet, the presentation of medical data to the specialist is made through specialized viewers (or players in the case of the stethoscope sound) for different types of medical data. These viewers can work differently depending on the kind of transmission of the specific medical data: real-time or store and forward. Most of the clinical examinations are collected using store and forward methods and are digitally stored in the patient's health record. The standard resting 12-lead ECG is one of them. A specific ECG viewer has been developed according to the SCP-ECG standard by ICS-FORTH for the display, the visual analysis and also the visual comparison of ECGs [6] on a standard PC. This viewer is currently used as a basic component in all the

applications developed in the HYGEIAnet project by cardiologists and GPs. Thus, as a first step, the development of a multi-vendor 12-lead resting ECG viewer for PDAs was begun.

2. Methods

Initially an investigation was made into the available PDA devices on the market. Currently the market is dominated by two platforms: Palm OS and Pocket PC [7].

Pocket PC devices typically offer a larger screen area, which is an important feature for quicker reading. Their 320 by 240 pixel screens offer higher resolution than Palm-based devices, which typically have 160 by 160 pixel screens, although new Palm OS devices with higher resolutions are coming on the market.

Usually Pocket PC devices have faster processors that, in combination with the larger screen, cause higher power consumption. Furthermore, the availability of Windows CE as operating system would allow an easy redesign of an ECG viewer already available for Win32 PC platform. Our final decision was to focus on Pocket PC devices.

2.1. Development environment

The Pocket PC application programming requires the use of special development tools such as the Microsoft Embedded Visual C++ (eVC3). These tools provide the Pocket PC SDK in order to build Windows CE programs and an emulator for testing them without the need of the physical presence of the pocket PC device. In general Windows CE is very similar to the MS Windows operating system, but has only a subset of the functionality because it was created to be able to run on devices with limited memory capability and resources such as CPU and screen resolution (compared to the standard PC). Developing applications for the Pocket PC is analogous to writing applications for desktop Windows. You basically need the same tools:

- ✓ A compiler, linker and debugger.
- ✓ A Software Development Kit (SDK).
- ✓ A workstation to run the tools on.

The main difference is the use of a device emulator on a standard PC for a quick test of the application before downloading to the physical device. In fact, the serial link between the development workstation and the target device does not allow rapid download and debugging so the use of the emulator is a normal practice.

2.2. Design choices

Having chosen the device and set up the development environment, automatically we are faced with the main constraints of the project. The limited size and resolution of the device screen do not allow a good reproduction of 10 seconds of 12-lead ECG in a single screen, as is usually preferred by cardiologists and GPs. Thus,

different design choices could be made. A possible solution was to maintain the image size of the standard PC ECG viewer and to allow navigation on this large virtual image with a mouse panning technique, but this approach is not usually well-accepted by the users, especially when the ratio between the visible area and the whole size of the image is significantly large. Another solution that seemed more suitable was to introduce changes in the user commands provided by the user interface, so that the application would display smaller parts of the ECG, but the user would have the possibility to navigate from one part to another. Finally we opted for this second solution, which also had the advantage of allowing the possibility to implement a significant level of zoom on the signal without losing the reference between the zoomed part and the original signal and continuing to maintain a simple user interface.

Another important aspect was the necessity of implementing a multi-vendor ECG viewer. We had already encountered the difficulties and the large efforts required in implementing parsers able to get all the necessary information from ECG files stored with proprietary formats, and sometimes the proprietary formats are not even disclosed, making this approach quite impossible. The only affordable way is to implement parsers for well-established ECG storage formats that are described according to standards “de jure” or “de facto” [8]. This is a sufficient warranty that the developed solution will not be targeted only at a specific manufacturer, even if in electrocardiography there is still a significant tendency to develop proprietary solutions. Thus, in accordance with the strategy used for the standard PC ECG viewer, we decided to implement an SCP-ECG parser, so that all the ECG files stored according to this standard could be parsed and successfully displayed. In practice, the SCP-ECG standard (CEN ENV 1064, ANSI/AAMI EC71) is currently the only existing standard for digital ECG communication and storage [9,10] and some companies worldwide have implemented this standard on their ECG devices.

2.3. Evaluation method

Once the ECG viewer for the Pocket PC had been developed, a further step was an attempt at its first assessment by general practitioners (GPs) and cardiologists. Thus, a questionnaire was prepared and distributed to some users before the release of the ECG viewer. The purpose of the questionnaire was larger than a simple assessment of the ECG viewer; its focus was also on the use of the ECG viewer in eHealth services and on the general use of PDAs in telemedicine applications.

3. Results

The development of the SCP-ECG file parser and the ECG viewer was carried out with a view to simplifying the user interface as much as possible, so that very little space was dedicated to the menus and other options, saving most of the screen for the ECG display.

In figure 1 the structure of the menu with its sub-menus is described:

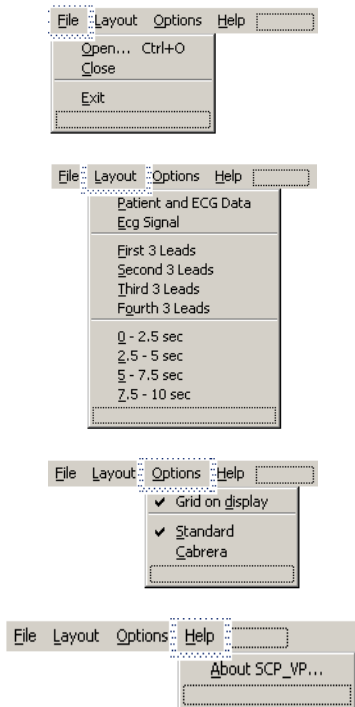


Figure 1. The structure of the menu bar.

In figure 2 is the ECG as it appears on the Pocket PC display.

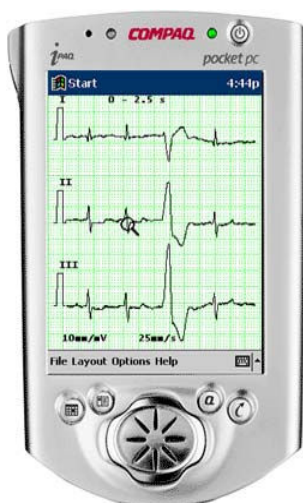


Figure 2. The ECG displayed on the Pocket PC screen.

The zoom function is available, as shown in figure 3.

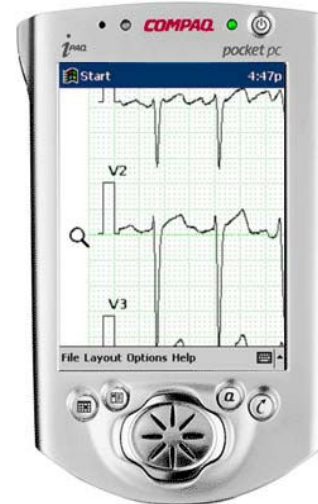


Figure 3. The zoom function.

The zoom function allows for a zoom factor up to a maximum of 400%.

By opening the Layout tab, the user can select the part of the ECG leads he/she wishes to observe (for example, first three leads from 0 to 2.5 seconds) by checking the appropriate options. Moreover, the layout tab provides the patient's file/information when we select the Patient and ECG Data option (see figure 4).

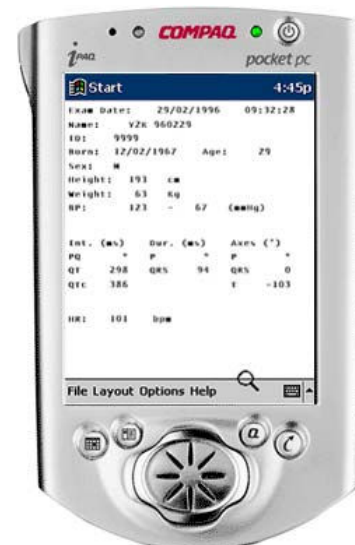


Figure 4. The patient data and the global measurement.

4. Discussion and conclusion

A longitudinal study was carried out to make a first evaluation of the doctors' attitudes to the introduction of the new ECG Viewer on the Pocket PC environment in the telemedicine applications already deployed in HYGEIAnet, as a first step towards its use in the

integrated health care record. This study highlights the importance of planning, effort, cooperation and an appropriate approach to this implementation in order for telemedicine using PDAs to be accepted. Thus, a questionnaire was prepared with the purpose to evaluate the telemedicine application and to measure the effectiveness and the quality of the Pocket PC ECG Viewer.

The surveys were conducted on the island of Crete at the Venizeleio Hospital of Heraklion and the Primary Health Care Centre of Anogeia, Rethymno. The participants were GPs and cardiologists. The procedure for completing the questionnaires was studied to assure an independent opinion by all the people interviewed. The questionnaire was not publicized and individually, for each person interviewed, a detailed demonstration of the equipment was given, supported by a power point presentation. After the demonstration the participant was asked to fill in the questionnaire. This procedure was repeated individually for each participant on different days and each participant was asked if he had known anything about similar interviews made with other colleagues (to assure the independent opinion). The collection of all data from the doctors lasted approximately two weeks. In order to compare responses between the participants, each one recorded their name, occupation, department and date of survey.

In the initial interviews, cardiologists and GPs were fairly positive about the telemedicine system and felt that it was both easy to use and reliable. The availability of PDA with the capability of ECG displaying was considered remarkable. The most frequent benefits of the ECG Viewer on PDAs were indicated in: easier access to staff and patients, time saving and increased quality of care. From a diagnostic point of view, in comparison to the quality of an ECG provided on paper, the ECG Viewer was rated good and very good in the context of benefits to patient care.

The results of these interviews confirms the general will of using PDAs by doctors, giving a further feeling that the PDAs diffusion should increase in the next years. The access to the multimedia patient record and the eHealth services through such devices will further on benefit the doctors providing them with the access to the integrated health care record from the point of need. On the other side, full ubiquity can be reached through PDAs with wireless connectivity, when they have the capability of displaying all the information available in the patient record including the clinical examinations with the necessary graphical details and without any need of sitting at a desktop station for their graphical display.

The conclusion of this first step encourages and stimulates the development of further components for the graphical support of other clinical examinations and vital signs displaying on a PDA.

Acknowledgements

The work reported in this paper was supported in part by the OpenECG project (IST-2001-37711).

The authors would like to thank E. Makrogamvrakis for his valuable contribution.

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Address for correspondence.

Franco Chiarugi
CMI-HTA,
Institute of Computer Science,
Foundation for Research and Technology - Hellas,
P.O. Box 1385 Vassilika Vouton,
GR 711 10 Heraklion, Crete
Greece
chiarugi@ics.forth.gr