Multimedia Paging for Clinical Alarms on Mobile Platforms

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Abstract

In the intensive care setting patient monitors generate many alarms. These alarms are frequently benign, but also unobserved as the caregiver is not at the location where the alarm is delivered. We developed a web-interface, integrated with an alarm manager that provides access to the "patient event" data. Alarm messages can be displayed by care unit and patient. Vital signs at the moment of the "patient event", as well as before and after can be displayed. The interface is compatible with the main Smartphone platforms (iPhone, Android, Blackberry, Windows Mobile and Symbian) and may facilitate a faster, more adequate response by caregivers to patient monitor alarms.

1. Introduction

Patients admitted to the Intensive Cardiac Care Unit are closely monitored and treated with different devices that generate alarms when an abnormality is detected. However, most alarms do not signify a life-threatening event. These alarms are typically provided by the patient care device, or at the central monitoring post at the nurse desk. However, caregivers are frequently away from either of these locations providing patient care or performing other tasks, and are not able to observe the alarms at all times. Additionally, default alarm settings are set up by the manufacturer to maximize sensitivity, at the cost of a high false positive rate [1]: most alarms do not signify a life-threatening event. Delivery of patient care device alarms directly to the caregiver could result in faster, more adequate reaction to the messages. Solutions that provide this to pagers, and/or other portable devices, however are frequently limited to a single device manufacturer. In addition most pagers are only able to display (limited) amounts of text.

Many other portable electronic platforms exist and the choice is rapidly increasing with the popularity of the 'Smartphone' and personal digital assistants (PDA). The clinical use of these devices is increasing, and many medical applications exist. However, these applications mainly provide disease specific information, and do not provide real-time patient specific data. Also, data is limited on the effectiveness of the use of portable electronic devices on patient care [2]. The aim of the current project was to develop a technical, web-based, solution that allows delivery of "patient events" directly to the clinical staff on widely available mobile devices.

2. Methods

The project was developed at the Thoraxcenter of the Erasmus Medical Center, Rotterdam, Netherlands. 78 beds over five care units are equipped with patient monitors. Each care unit is connected to a central gateway [3]. Patient monitoring are automatically collected from the network and stored in a SQL database using the intelligent Patient Universal Tele Alarm framework (i-PUT) [4], an open source toolkit [5]. Briefly, i-PUT uses ASP.NET 1.1, C#, SOAP and AJAX to collect and manage the alarms from the gateway.

Table 1: Overview of Smartphone platforms

	iPhone OS	**Android OS**	**Windows Mobile**	**BlackBerry**	**Symbian OS**
Resolution	480x320	480x800	480x800	480x360	640x360
Wi-Fi / 3G	V / V	V / V	V / V	V / V	V / V
HTML / Canvas	V / V	V / V	V / V	V / –	V / –
JavaScript	V	V	V	V	V
Java applet	–	–	V	–	–
Flash	–	–	V	V	V
SDK	Objective C	Java ME	.NET	Java ME	Java ME
Models investigated	iPhone 3G, iPod Touch	Nexus One, G1	HTC HD2, HTC Touch2, Samsung B7610	Curve 8900, Tour 9630, Bold 9700	Nokia 5230, Nokia E71

Determination of primary requirements:

First, we determined which data was valuable enough to present. To do this literature review and consultation of physicians and critical care nurses was done. Key questions were: Which clinical and non-clinical data needs to be directly displayed with a patient alarm? Which clinical data needs to be accessible to asses if the alarm requires further attention? How should alarms from different patients and care-units be displayed?

Determination of general system requirements:

The user interface needed to be straight-forward and consistent. The system was not permitted to cause fatal errors on any of the devices the system was used on. When displaying an alarm, the system needed to provide accurate information, applicable to the alarm and the patient that it originated from. The system was intended as an enhancement, and not a replacement for the alarms generated by patient care devices.

Web interface requirements:

The web-based interface needed to be accessible on various mobile devices. An overview of the different devices is given in Table 1. For the final design we chose to use a combination of HTML, Java-Script and server side generated PNG-images.

The system needed to provide access to recent alarms. To access each specific alarm the system needed to provide a list of all multimedia pages.

3. Results

Taking these requirements into account, the system was developed over a period of 6 months. We developed a web-interface, integrated with an alarm manager that provides access to the "patient event" data. An overview of the system is given in Figure 1.

To achieve this data was accessed from TapeRec [3], a system that stores patient monitoring data including vital signs and signal curves up to 72 hours for all admitted patients. Thus we were able to display the vital signs at the moment of the "patient event", as well as the vital sign signals from 5 seconds before until 5 seconds after the "patient event". The exact times are configurable.

The interface can be configured to display alarms for each patient bed or for an entire care unit and is updated every 5 seconds with new alarms. By clicking on an alarm, the message and vital signs displayed by the monitor at the moment of the alarm are displayed, enabling the user to make an informed decision regarding further action.

The system also provides a mechanism to add additional messages. Messages that could be included in the system are messages from patient care devices not attached to the monitoring gateway, the arrival of new lab result, or from a clinical decision support system.

To deliver the alarms that are provided by the web-interface directly to the caregiver, it needs to be accessible from, preferably, a mobile device. We tested the interface on a number of different platforms,

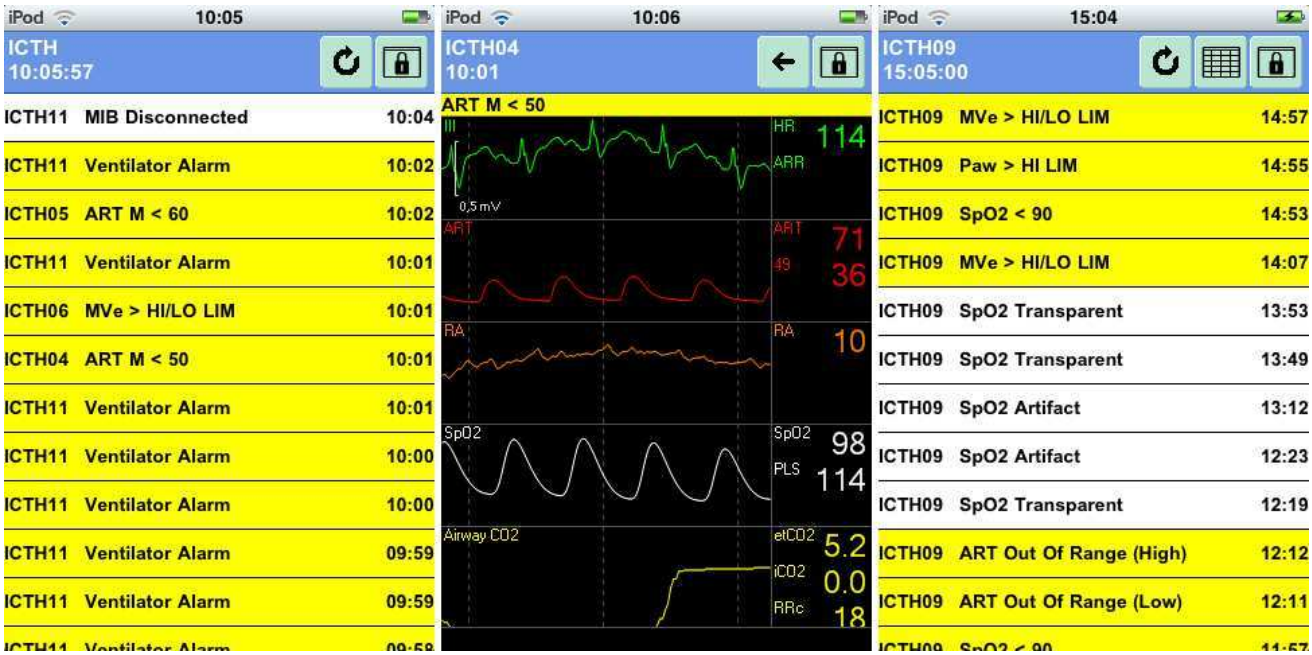

Figure 1: Example of multimedia paging interface. The severity of the alarm indicated by the background color. The left panel shows the alarms for a care unit, the center panel displays the vital signs at the moment of an alarm, the right panel displays all alarms for a patient bed.

Table 2: Overview of tested devices

	iPhone OS	Android OS	Windows Mobile 6.5	Black Berry	Symbian OS
Tested device	iPhone 3G	G1	Samsung B7610	Bold 9700	Nokia E71
Alarm list	V	V	V	V	V
Scroll list	V	V	V	–	–
Care Unit navigation	V	V	V	V	V
Bed specific	V	V	V	V	V
Show waveforms	V	V	V	V	V
Navigate waveforms	V	V	V	–	V
Scroll waveforms	V	V	–	–	–
Remarks			Opera Mobile, display issue		

including Smartphones. An overview of the main types is given in Table 2. The iPhone and Android platforms were able to display all of the web-interface features; Windows mobile 6.5 and Symbian were able to display the essential features; the feature of viewing vital sign tracings before and after the event was limited on the Blackberry to those at the moment of the actual alarm.

4. Discussion

We developed a multimedia paging application to allow delivery of alarms and clinical data directly to the caregiver on a portable electronic device.

Many manufactures of patient care devices also provide output of the alarms to different modalities. Paging devices are widely accepted and in use in most hospitals. However, they are limited in their ability to display information (limited number of characters and inability to display graphics). Increasingly, manufacturers are providing output to other modalities, including PDA's, sometimes using web-based technology. These solutions however are limited to a single manufacturer, and not yet widely in use. The current system, on the other hand, is expandable to other devices from different manufacturers, and provides support for multiple mobile platforms.

Applications are available that provide continuous access to patient monitoring data, however they are not event triggered, requiring continuous attention of the caregiver [6]. These applications could be a useful add-on to the current system, enabling access to real time data in the case of an alarm.

Future development of smart-phone and PDA based applications that allow access to clinical systems is likely to be difficult; currently different manufacturers provide their own platforms. Thus to provide access to the same clinical system from different Smartphone devices, different versions of the application need to be developed for each device, inevitably leading to an unsupportable system. Two possible solutions to this problem exist. First option is to choose one device for the application. This would however, lead to a restriction in the applicability of the application in different hospitals, or even over different departments. In certain environments there might be reasons to choose a different device, also availability may differ in different countries. In a 'worst case' scenario this would lead to the care provider carrying a number of different devices for different systems.

We propose a different approach: use of uniform web-based technologies to develop these applications. Most current, and all new Smartphone and PDA devices support a subset of the standard the web technologies (HTML, Java-Script). A joint support of more powerful web-based technologies by the device manufacturers would be an important step forward. Whether this would be achieved by implementing current technology (HTML5, Java or Flash) or a new technology (still to be developed) is irrelevant, but most importantly it should be tackled jointly by all Smartphone manufacturers.

A further development of standards for patient monitoring device communication is needed to ensure reliable and complete exchange of vital patient information in between devices from different manufacturers [4,7].

Clinical evaluation of the system is needed to determine the effect on patient care: does delivery of critical alarms to the caregiver on a mobile device lead to a faster and more appropriate response? Also work is needed to enable the system to display new laboratory results, or CDSS results (for example an automated insulin protocol [8]). Other improvements might be viewing the patient directly via webcam, supplying trends in clinical data over a prior time period and provide access to clinical charting data.

An advantage of the current system is that evaluation of its use is possible using the alarm database; thus the effect of user targeted interventions to reduce alarm

frequency can be evaluated. When combined with a rule-engine, “smart alarms” could be generated that utilize data from different monitoring devices, laboratory results and/or decision support messages. A different advantage of using a Smartphone platform is that it could also be used by caregivers to communicate with each other.

A limitation of the current architecture is the need for network access, during initial testing there were many Wi-Fi “dead-spots”. A solution would be improved Wi-Fi access, or use of a different network type. Due to this limitation it is important to have the existing patient monitors active, to ensure that the alarms are displayed even when they are not delivered to the mobile device. A further limitation is that the current system only provides one-way communication. Technically it would be possible to silence alarms from the mobile device, also the Smartphone platform could enable the care-giver to talk directly to the patient. Future work is needed to investigate the feasibility of these enhancements.

A demonstration of the capabilities of the current system can be viewed at: http://www.spotchecker.eu/

5. Conclusion

We developed a web-based interface to display patient care device alarm messages and provide access to vital patient data at and around the time of the alarm. Alarm messages can be displayed by care unit and by patient. The interface is compatible with the main Smartphone platforms and may facilitate a faster, more adequate response by caregivers to patient monitor alarms.

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