Real-time interactive medical consultation using a pervasive healthcare architecture

Bingchuan Yuan, John Herbert,
Department of Computer Science, University College Cork, Ireland
{by2,j.herbert}@cs.ucc.ie

Abstract. The phenomenon of an aging society has derived problems such as shortage of medical resources, rising healthcare costs and reduction of quality in healthcare services. Pervasive healthcare aims to alleviate these problems, but many issues remain to be resolved. This paper presents a system called CARA (Context Aware Real-time Assistant) whose design goals are to address these issues in a pervasive long-term healthcare solution. CARA aims to provide efficient healthcare services by adapting the healthcare technology to fit in with normal activities of the elderly and working practices of the caregivers. This system can continuously measure physiological signals, and either store the data on the server or stream the data to a remote location in real-time. A design goal of ubiquitous access has prompted the design of the system as a rich internet application. The only tool required is a web browser with the commonly-available Adobe Flash plug-in installed. Thus the system enables access and analysis on any internet-connected PC or appropriate smart device, independent of geographic location. The remote monitoring and data review applications of CARA are presented at as the main implementation examples. The results of experiments using the system are presented.

Keywords: Pervasive Healthcare, CARA, Data Review, Remote Monitoring, Rich Internet Application.

1 Introduction

While life-expectancy continues to grow, at least in some countries, the inequality in life expectancies and Healthy Life Years (HLYs) [1] remains large. This means that many people live longer but in a state in which chronic conditions substantially affect their quality of life. Furthermore, this inequality has a negative impact on healthcare costs.

One proposed solution to the current crisis is pervasive healthcare [2]. The wide scale deployment of wireless networks will improve communication among patients, physicians, and other healthcare workers as well as enabling the delivery of accurate medical information anytime anywhere, thereby reducing errors and improving access. At the same time, advances in wireless technologies, such as intelligent mobile devices and wearable networks, have made possible a wide range of efficient and powerful medical applications. Pervasive healthcare has the potential to reduce long-term costs and improve quality of service [3-7].

In this paper we present the CARA pervasive healthcare architecture, with the focus on its web-based real-time remote medical consultation application. The main components of the CARA system are:

1. Wearable Wireless Sensors.

A key component of the system is a BAN (Body Area Network, i.e. a portable electronic device capable of monitoring and communicating patient vital signs), and this includes medical sensors such as the ECG, SpO2, temperature and mobility sensors.

2. Remote Monitoring System.

This is responsible for remotely controlling the BAN and continuously measuring physiological signals of the elderly through the BAN and internet connection. A web camera is integrated to this application that may be used for monitoring and for interaction between the elderly and the caregiver.

3. Data & Video Review System.

This is designed for medical consultant or caregiver to review the data previously collected from the elderly in case s/he might be not available for real-time monitoring. This application not only can present the recorded data in graphic chart but also allows the consultant to view the recorded video of the elderly along with real-time sensor data.

4. Healthcare Reasoning System.

This is implemented by a Windows Workflow Rule Engine, and applies medical rules, appropriate for the individual, to real-time data that is received from the vital sign sensors. A real-time human movement monitoring function has been added in this system which can provide valuable information regarding an individual's degree of physical ability and general level of daily living activities.

2 System Prototype

The current CARA system prototype provides remote physiological signal monitoring with on-demand video recording services, along with a data and video review functionality to assist diagnosis. An overall architecture of the CARA healthcare system is shown in Figure 1.

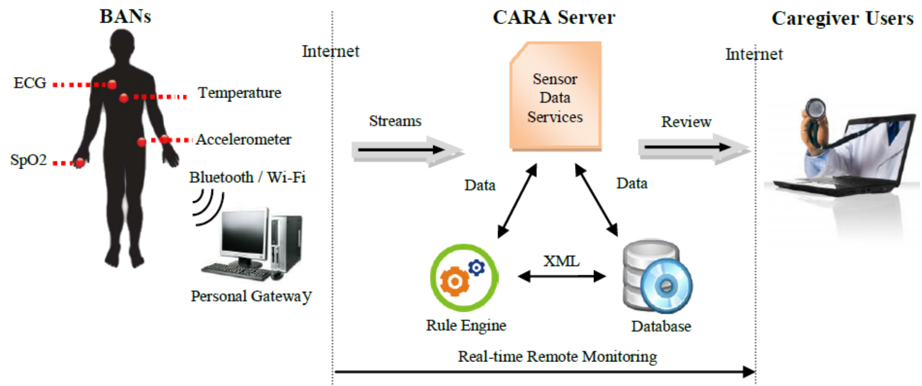

Fig. 1. CARA system architecture

The remote monitoring is able to provide continuous real-time physiological signal monitoring over the internet, and it is also able to send alarms when an emergency is detected. The on-demand video monitoring can be used to provide a live video service in case the caregiver needs more information of the patient. All the sensor readings and video records are stored in the database on the CARA server so that the caregiver can review the data anywhere anytime.

The wireless monitoring devices which are the basis of the body sensor network are developed by the Tyndall Institute of University College Cork. The sensor platform is a generic 25mm×25mm module that has been deployed in applications ranging from medical measurement to agriculture.

3 System Implementation

The CARA system is designed as a web application for physicians to monitor patients remotely. In traditional web applications, there is a limit to the interactivity that can be added to a single page. With RIA (Rich Internet Applications) technologies, the client computer and the server can communicate without page refreshes. This allows the real time user interaction which satisfies an essential requirement of our system. Adobe Flex is one of the latest trends in the realm of Rich Internet Applications. It was chosen for its ubiquity since it is estimated that over 90% of web users now have the Flash Player installed on their computers.

3.1 Real-time Remote Monitoring System

By using the remote monitoring system, caregivers can monitor patients' biological signals remotely through their web browser (Figure 2). Since the data is transmitted in real-time, a remote consulting physician is able to interact with a patient and observe real-time vital signs. As internet access becomes more readily available, this application becomes a convenient and effective tool for supporting healthcare services.

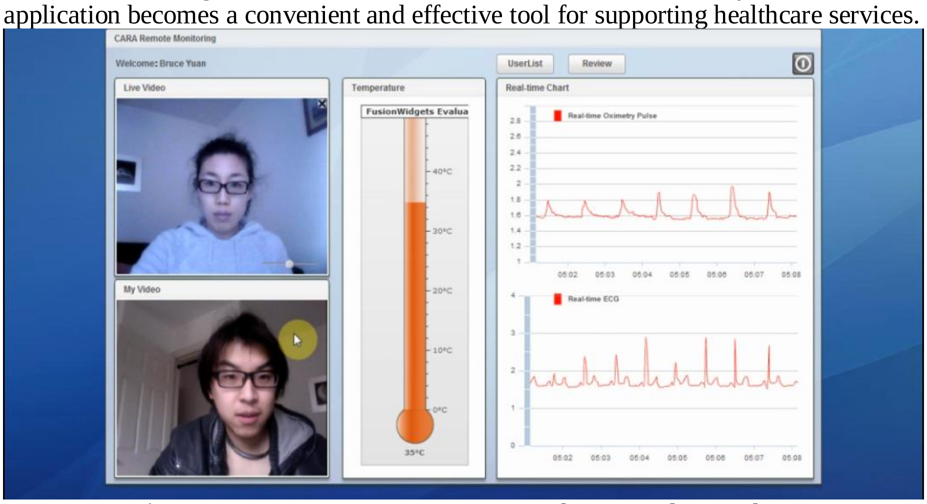

Fig. 2. Remote Monitoring Integrate With Live Video Application.

3.2 Data Review System

The data review system includes sensor data review and video replay applications. The sensor data review application allows the caregiver to analyze the full context of the sensor readings for a selected patient within a certain time period in order to distinguish critical from non-critical situations.

The video replay application is designed for the caregiver to review the recorded patient session video along with the associated real-time sensor data. This function is based on the real-time remote monitoring system. Whenever the patient's live video stream is published on the Flash Media Server (FMS), it is also recorded as a flash video file (FLV) on the server. To characterize the video file and to synchronize with the sensor data, several annotations of the video must be recorded into the database as well (e.g. video start time, end time, patient information).

3.3 Healthcare Reasoning System

The Healthcare Reasoning System provides a general rule engine that can be tailored with different rules for different applications (such as for in-clinic assessment or at-home monitoring), and it also executes in real-time and offers immediate notification of critical conditions. Some critical conditions may only be identified from correlating different sensor readings and trends in sensor readings accumulated over time.

The Healthcare Reasoning System is capable of performing three main reasoning tasks: (i) continuous analysis of the vital sign readings in the context of all other available information, (ii) prediction of possibly at-risk situations and (iii) notification of emergency situations indicating a health risk. Raw data coming from sensors is processed by the context management services, producing higher-level information. After this, the rule engine identifies the current state of the patient, following a triage-style model, as (normal, at-risk or emergency). Further analysis in the next step means that if the current inputs (physiological values) are atypical for the patient, an alert output might be upgraded to an emergency. The generated data is stored to assist other decisions and for additional analysis.

4 Non-functional Requirements

Several non-functional/quality requirements are taken into account in the design of the CARA system.

Two experiments were conducted to test the CARA system's physical performance. The first experiment is to evaluate signal quality between the wearable monitoring devices (WMD) and a gateway PC at different distances. We fixed the location of the gateway PC and tested wireless communication link quality at distances ranging from 1m to 15m from the WMD. We found that the closer WMD offered better transmission quality (see Table 1). The signal to noise ratio (SNR) value was also affected by some obstructions such as doors or movement of the subject.

Table 1. SNR Value of the WMD

WMD	Distance		
	1m	***7m***	***15m***
SNR(dB)	11	20	33

The second experiment is to evaluate the impact of the potential delay of the network. We tested our remote monitoring system through localhost, intranet and internet respectively, and the results indicating data transmission delay in milliseconds are 50, 200 and 700. The delay caused by internet latency is unavoidable under the current approach. However, this delay does not significantly affect the working of this system.

5 Conclusions

The CARA pervasive healthcare system presented here provides a technical solution for obtaining immediate expert diagnosis when that expert is not around. While it is possible that this service might be available to a patient at home, it is more immediately practicable to use in a remote general practice clinic where the placement of the BAN and use of the equipment may be supervised by a medical attendant. Important aspects of this system include: inter-visibility between patient and caregiver; real-time interactive medical consultation; and replay, review and annotation of the remote consultation by the medical professional. The annotation of significant parts of the multi-modal monitored signals by the medical professional can provide the basis for the automated intelligent analysis of the CARA system. The application was discussed in the context of the overall CARA healthcare architecture, and results of some experiments using the application were presented.

References

1. C. Jagger et al.,: Inequalities in healthy life years in the 25 countries of the European union in 2005: a cross-national meta-regression analysis. vol. 372, pp. 2124-2131. The Lancet (2008)
2. Varshney, U.: Pervasive healthcare. Computer 36, 138-140 (2003)
3. Bardram, J.E., Mihailidis, A., Wan, D.: Pervasive computing in healthcare. CRC, Boca Raton, Fla. ; London (2007)
4. Varshney, U.: Pervasive Computing and Healthcare. Pervasive Healthcare Computing, pp. 39-62. Springer US (2009)
5. Sordo, M., Vaidya, S., Jain, L., Doukas, C., Maglogiannis, I.: Intelligent Pervasive Healthcare Systems. Advanced Computational Intelligence Paradigms in Healthcare, vol. 107, pp. 95-115. Springer Berlin / Heidelberg (2008)
6. Copetti, A., Loques, O., Leite, J.C.B., Barbosa, T.P.C., da Nobrega, A.C.L.: Intelligent context-aware monitoring of hypertensive patients. In: Conference Intelligent context-aware monitoring of hypertensive patients, pp. 1-6. (Year)
7. Bentsen, P., Nielsen, J.H., Nybo, J., Ring, C., Wagner, S.: Continuous healthcare. In: Conference Continuous healthcare, pp. 1-2. (2010)