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An Efficient Component-Based Framework for Intelligent Home-Care System Design with Video and Physiological Monitoring Machineries

Chuan-Yen Chiang[1] Yen-Lin Chen[2] Chao-Wei Yu[2] Shyan-Ming Yuan[1] Zeng-Wei Hong[3,*]

[1]Department of Computer Science,
National Chiao Tung University, Hsinchu, Taiwan

[2]Department of Computer Science and Information Engineering,
National Taipei University of Technology, Taipei, Taiwan
Email: ylchen@csie.ntut.edu.tw

[3]Department of Computer Science and Information Engineering,
Asia University, Taichung, Taiwan
[*]Email: stewart@asia.edu.tw

***Abstract*—This study proposes a customized and reusable component-based design framework based on the UML modeling process for intelligent home healthcare systems. All the proposed functional components are reusable, replaceable, and extensible for the system developers to implement customized home healthcare systems for different demands of patients and caregivers on healthcare monitoring aspects. The prototype design of the intelligent healthcare system based on these proposed components can provide the following features: 1). the system can monitor and record the videos of rehabilitation situations and actions of the patient by multiple CCD cameras, and the monitoring videos at different times can be accordingly stored in the archive. 2). the system can record the patient's physiological data records and the corresponding treatment plan, and these records can be stored in a XML archiving database for caregivers' review. 3). during the times for the patient to take medicine or other healing activities listed on the given treatment plan, the system can automatically alarm the patient and record the patient's treatment situations. 4). The patient's caregivers and family members can ubiquitously monitor the videos and physiological records of the patient's rehabilitation situations via the handheld mobile devices via the internet or wireless communication networks. 5). The caregivers and patients can setup the alarm machinery for the patients' physiological warning states, and once the patients' physiological states suddenly deteriorate, the module will immediately alarm the caregivers by sending notification messages to their remote mobile devices or web browsers.**

Keywords-video monitoring; healthcare systems; patient monitoring; mobile devices; component-based framework.

I. INTRODUCTION

Nowadays, home healthcare approaches or systems for elder and chronic disease patients have been an important research field. Due to large work loading of the career people in the current industrialized nations, maintaining long-time and face-to-face homecare for their elder or chronic disease family members becomes a difficult challenge to most families in modern life. With the technical development of the information and communication technology (ICT), the new homecare techniques and products based on the ICT technologies have progressively entered modern family life, such as wireless emergency telemedicine systems, elder people's home emergency rescuing systems, infant monitoring systems, mobile healthcare systems, and handheld electronic patient records[1]-[9].

Because of different demands for providing healthcare services to the patients with different health and disease conditions at various rehabilitation environments and places, a flexible intelligent home healthcare system should provide customized functionalities for the caregivers or system developers to design the best-fitted healthcare systems for each individual patient with different healthcare demands. However, most of the above-mentioned present healthcare techniques and systems [1]-[9] are designed for providing some specific healthcare functions for pre-determined patients, and are not easy to extend and improve the healthcare services for different demands of the individual patients and caregivers. Therefore, this study will propose a customized and reusable component-based design framework for intelligent home healthcare systems. In this study, all the proposed functional components are reusable, replaceable, and extensible for the system developers to implement customized home healthcare systems for different demands of patients and caregivers on healthcare monitoring aspects.

The proposed component-based framework for intelligent home healthcare systems based on the UML modeling process [10] includes four major components: the real-time video codec component, the physiological information and treatment monitoring component, the monitoring information transmission component, and the remote patient monitoring component. The prototype design of the intelligent healthcare system based on these proposed components can provide the following features:

1) The system can monitor and record the videos of rehabilitation situations and actions of the patient by multiple CCD cameras, and the monitoring videos at different times can be accordingly stored in the archive.

2) The system can record the patient's physiological data records and the corresponding treatment plan (such as the

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schedule of taking medicines), and these records can be stored in a XML (Extensible markup language) archiving database for caregivers' review.

3) During the times for the patient to take medicine or other healing activities listed on the given treatment plan, the system can automatically alarm the patient and record the patient's treatment situations.

4) The patient's caregivers and family members can ubiquitously monitor the videos and physiological records of the patient's rehabilitation situations via the handheld mobile devices via the internet or wireless communication networks by installing the needed portable software components of remote monitoring functions.

5) The caregivers and patients can setup the alarm machinery for the patients' physiological warning states, and once the patients' physiological states suddenly deteriorate, the module will immediately alarm the caregivers by sending notification messages to their remote mobile devices or web browsers.

II. SYSTEM FRAMEWORK AND IMPLEMENTATION

To provide a flexible, convenient, and extensible home-care system for patients and caregivers, the proposed home-care monitoring system is implemented based on an extensible component-based framework. This component-based framework is composed by the following reusable modules,

1) Real-time video codec component: This component integrates the proposed fast and real-time monitoring video compression and decompression technique, to computational effectively record the monitoring videos of the patient's rehabilitation situations and living actions at home with high visual quality and frugal storage spaces. Besides, the proposed codec component also support portability for working on various devices and web browsers, and also implement a set of flexible software interfaces for recording and retrieving the monitoring videos, to provide convenient and rapid development of different application specific local and remote health-care monitoring systems.

2) Physiological information and treatment monitoring component: This component can measure and acquire the patient's physiological data records from sensors, such as electrocardiography (ECG), body temperatures, heart rates, blood pressures, blood oxygen values, breath meters, and record the treatment plans according to the doctor's prescriptions in a XML archiving database. The recorded physiological data records and treatment plans can be conveniently retrieved and viewed by the caregivers via various devices or web browsers. The caregiver can also adopt this component to set up alarm schedules according to the patient's treatment plans as well as set up the alarm machinery for the patients' physiological warning states, and the component will timely alarm the patient to obey the treatment process, such as the times needed to take a dose of medicine, and will immediately alarm the caregivers when the patients' physiological statuses get worse.

3) Monitoring information transmission component: The transmission component is cooperated with the above-mentioned real-time video codec component and the physiological information and treatment monitoring module for transmitting the patient's monitoring videos, physiological data records and treatment records to the remote client-side devices and web browsers of the caregivers via Internet and mobile communication networks. The transmission module utilizes RTP (Real-time Transport Protocol) to transmit streams of the patient's monitoring videos, while uses TCP/IP protocol to transmit the patient's physiological data records, treatment records and warning states.

4) Remote patient monitoring component: To support the remote patient monitoring applications, this component, the real-time video codec component, and the physiological information and treatment monitoring module are conveniently released and can be easily installed in the remote client-side devices and web browsers of the caregivers. Thus, the caregivers' mobile devices or web browsers can request and get the patients' monitoring video streams, physiological data, treatment records and alarm messages of warning states from the main health-care monitoring system at home, then these videos and data can be displayed and retrieved by applying the client-side real-time video codec component and the physiological information and treatment monitoring component.

The overall system framework of the proposed home-care monitoring system is illustrated by the use-case diagram in Figure 1.

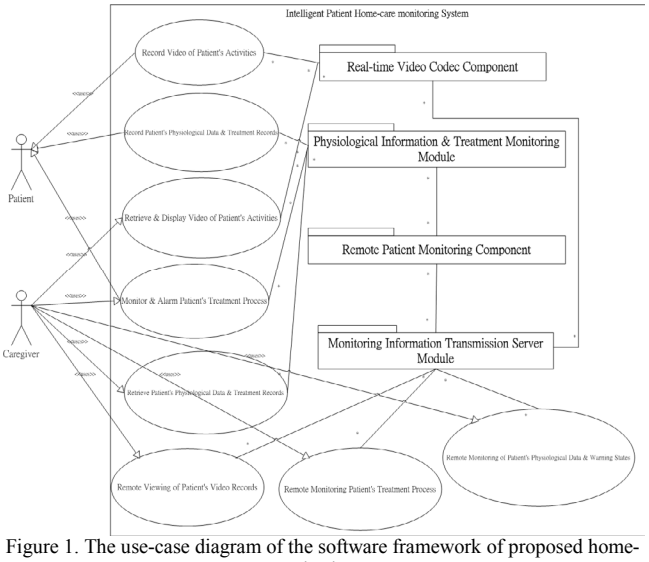


Figure 1. The use-case diagram of the software framework of proposed home-care monitoring system

III. RESOULTS AND DISCUSSIONS

This study presents an efficient component-based design framework of an intelligent home healthcare system. In the previous sections, the uses and functionalities of each component are clearly depicted and described based on the

UML modeling process, and are integrated into a complete class diagram as illustrated in the Figure 2. As can be seen from Figure 2, the connection and cooperation of the components and modules for building-up a flexible intelligent home healthcare system is comprehensible for the system developers on implementing and maintaining the customized home healthcare systems. All the software components and modules in this component-based design framework are reusable, replaceable, and extensible for the system developers to establish customized home healthcare systems for different demands of patient healthcare monitoring aspects. For instance, using different number of cameras and physiological sensor devices for monitoring various numbers of patients of different diseases and ages can be customized the healthcare systems by changing the configurations of the real-time video codec components and the physiological information and treatment monitoring modules.

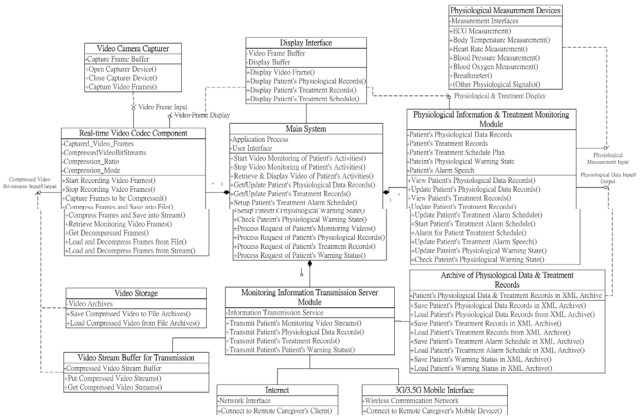
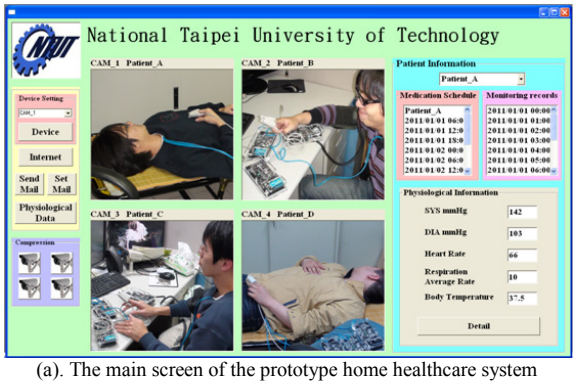


Figure 2. The integrated class diagram of the proposed component-based healthcare system framework

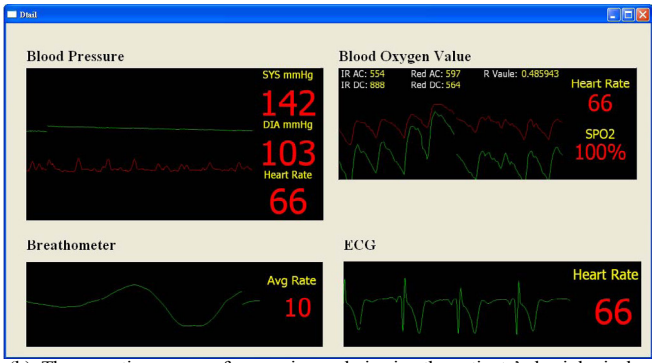
The prototype home healthcare system, which was implemented based on the proposed component-based framework by integrating the real-time video codec components, the physiological information and treatment monitoring module, the monitoring information transmission component, and the remote patient monitoring component, is shown in Figure 3. This prototype implementation of the home healthcare system integrated four CCD cameras to provide the capability of monitoring four rooms or places, a set of physiological measurement devices, including the measurement devices of the electrocardiography (ECG), body temperatures, heart rates, blood pressures, blood oxygen values and breath meters, and a network device for transmitting the monitoring videos, physiological data, treatment records and warning messages. The main system of the prototype healthcare system was implemented on a PC platform with a 2.4 GHz Pentium IV CPU with 1 GB DRAM, by using the Visual C++ 2008 development tools. The main patient monitoring screen of this prototype home healthcare system is shown in Figure 3.

As can be seen the main operating screen depicted in Figure 3(a), we can find that the home healthcare system can simultaneously monitor four different rooms or places of patients' activities, the patients' basic physiological data records, warning statues, and treatment records, as well as provide the archived monitoring videos, physiological and treatment records for the patients and their caregivers' retrieval. As the operation screen shown in Figure 3(b), the home healthcare system can provide advanced operational functionalities to measure and display the patient's physiological signals, including the ECG, blood pressures, blood oxygen values, and breath meters, and then record these physiological signal records for further retrieving by the patients and the caregivers.

Regarding to the remote monitoring functionalities of the patients' rehabilitation conditions, the caregivers can use the web browsers (as depicted in Figure 4(a)) or mobile devices (as depicted in Figure 5(a)) to remotely check and retrieve the patients' monitoring videos, physiological data and treatment records. Besides, the patients' detailed physiological data, including the ECG, blood pressures, blood oxygen values, and breath meters, can also be conveniently checked by using the remote physiological data display interfaces of the web browsers or mobile devices, as shown in Figure 4(b) and Figure 5(b), respectively.

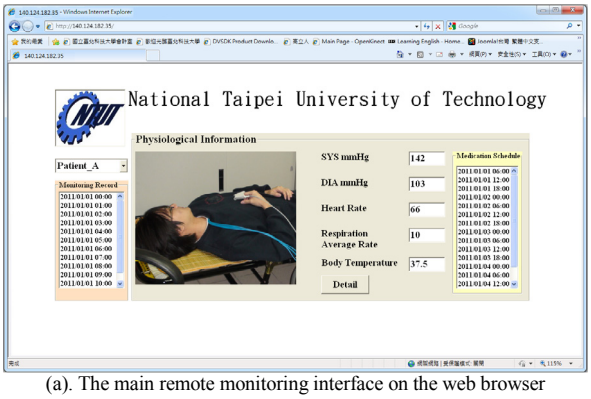


(a). The main screen of the prototype home healthcare system



(b). The operation screen of measuring and viewing the patients' physiological data records

Figure 3. The prototype system implemented by the proposed component-based healthcare system framework

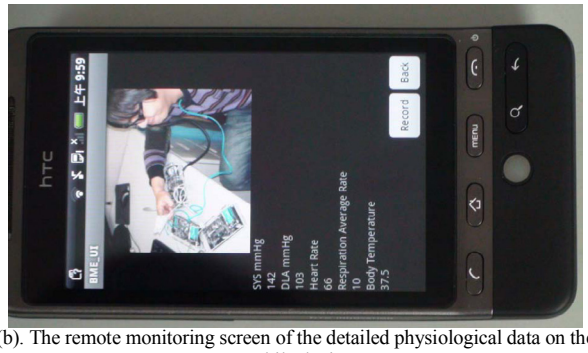


(a). The main remote monitoring interface on the web browser

(b). The remote monitoring screen of the detailed physiological data on the web browser

Figure 4. The remote monitoring interfaces of the web browsers

(a). The main remote monitoring interface on the mobile device



(b). The remote monitoring screen of the detailed physiological data on the mobile device

Figure 5. The remote monitoring interfaces of the mobile devices

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