Design of a Portable Tele-homecare Monitoring System for the Elderly

Abstract

This paper presents an on-going project of a Portable Tele-homecare Monitoring System (PTMS) for the elderly developed in Gerontechnology Research Center, Yuan Ze University. Instead of using a centralized database structure that gathers data from many households, in PTMS a household is the fundamental unit for data transmission, storage, and analysis. Equipped with different sensors, PTMS can be used for long-term personal health data management of the elderly in a home environment. PTMS also provides care-givers with convenient access to the health data of the elderly, and real time event-driven messages in urgent situations. Several PTMS applications are demonstrated, including environment and daily behavior monitoring, an RFID-based entrance guard system, sleep quality monitoring, vital sign monitoring, and a tele-presence robot.

Key words: Gerontechnology, tele-homecare, telepresence.

1. Introduction

According to UN’s definition, a society in which more than 7 percent of the total population is aged 65 or over is referred to as an aging society. Taiwan has become an
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Aging society since 1993. Currently the population aged 65 or older is over 2 million. The needs of health care and management for the elderly has become an important issue.

The increasing needs for elderly care cannot be solved by increasing the number of care-givers. To respond to the question, “How can technology be best used to support the needs of aging society?” the interdisciplinary research field “Gerontechnology” was introduced in the early 1990. Gerontechnology includes the research and development of techniques and technological products, based on the knowledge of aging processes, for the benefit of a preferred living and working environment and adapted medical care for the elderly[1]. Gerontechnology Research Center (GRC) of Yuan Ze University (YZU) was established in January, 2003. Currently the major research area in GRC is on tele-homecare.

Tele-homecare can be defined as the use of information and communication technologies to enable effective delivery and management of health services at a patient’s residence[2]. Home has become the centerpiece of health delivery system today, and significant activity is underway in the development of the tele-homecare equipment. Commercial systems are available in Europe, North America, and Japan. Most systems provide vital signs sensing in the home environment for monitoring chronically ill patients. Figure 1 shows the number of US patents in tele-homecare in the past 30 years. Clearly, tele-homecare is a rapidly growing area.
Most tele-homecare systems adopt the following sequence: sensing of various vital signs ➔ data transmission ➔ data storage and analysis ➔ medical actions. Figure 2 shows a typical example of a tele-homecare system, “SUKOYAKA Net-i” from NEC “SUKOYAKA Family 21 Plan”. Users use the terminals at home or public places to measure their vital signs, such as blood pressure, heart rate, ECG, weight, body temperature, etc., and the data is sent to the health welfare center through the Internet. Medical institutions can access the health data and take necessary actions.
A centralized database is often used in this structure for data storage and analysis, and the “health welfare center” partnering with a medical institution plays the major role. Users subscribe to a service from the health welfare center, instead of buying a product. Telephone line and the Internet, which are readily available in most homes, are commonly used for transmission of data. To “mobilize” the measuring devices, wireless communication technologies have been implemented into the measuring devices.

Though all technologies required are readily available, there has not been a successful commercial tele-homecare system in Taiwan yet. In 2002, a company called “Asia Pacific Telehealth Technologies” introduced a tele-health service system from MEDCAN Health Management Inc., which provided FDA-approved vital sign measuring devices, personal health data management service, and on-line consultation and diagnosis. However, this system was not well accepted and has been terminated. In our observation, the cost of such tele-homecare service is too high, and this cost is not covered by medical health insurance, seem to be the main reasons.

This paper describes a Portable Tele-homecare Monitoring System (PTMS) developed by GRC, YZU. Instead of using the centralized database structure that gathers data from
many households, in PTMS a household is the fundamental unit for data transmission, storage, and analysis. In this distributed structure, PTMS is a product-oriented system instead of a service-oriented system. The word “portable” means all devices of PTMS are designed to be modular and portable, and PTMS can be easily customized and installed in a home environment. Equipped with different sensors, PTMS can be used for long-term personal health data management of the elderly in a home environment. PTMS also provides care-givers with convenient access to the health data of the elderly, and real time event-driven messages in urgent situations. PTMS also has possible home security and smart house applications.

Section 2 of this paper describes the structure of PTMS, and Section 3 presents the applications already developed in YZU GRC. Section 4 describes an extension of PTMS, the “Telepresence Robot” developed in YZU GRC. Finally Section 5 outlines the possible future developments.

2. The Structure of PTMS and the Distributed Data Server

Figure 3 shows the structure of PTMS. Sensing signals from sensors embedded in the home environment are transmitted to the distributed data server (DDS), which is the core component of PTMS. Sensing signals are then processed and stored in the DDS. Remote users can request data from the DDS using an IE browser (through an application server) or a VB program. Event driven messages, cell phone messages or emails can be sent to specified care givers when urgent situation is detected.
Figure 3. The structure of PTMS

Figure 4 shows a picture of DDS, which is consist of a PIC server mounted on an application board. The PIC server contains a PIC microcontroller and a networking IC. It provides networking capability and can be used as a web server. Most peripheral functions of DDS are built on the application board. The application board (as well as the program in the PIC microcontroller) can be easily customized to adapt to different sensors and applications.

Figure 4. Distributed Data Server
Internet and serial interface (RS-232) are the primary communication interfaces of DDS with client PCs and other devices. DDS also receives external signals (e.g., sensor signals) through specific analogue or digital I/O ports. DDS also provides I2C (Inter-Integrated Circuit) communications to allow connections with external modules. For example, In addition, a GSM short message service module can be optionally connected to the DDS via I2C, which makes it possible to send text messages from DDS to specified caregivers when urgent situation is detected. DDS can also connect to a wireless LAN card and becomes a wireless device itself.

Long term health monitoring data are processed stored in an MMC card in DDS. Remote users can request for historical health monitoring data through an application program or an IE browser. Further data analysis or processing (such as authorization management, creating graphical displays, tables, etc.) can be built in application programs or an application server. Comparing with using a PC as a home server, DDS is low-cost, has smaller package, consumes lower energy (thus can be powered by batteries), is not affected by virus, and is safer and more reliable.

There are several advantages of the PTMS structure over the traditional centralized-database structure:

(1) The scale of PTMS is much smaller. A single household can be a running unit of PTMS. The infrastructure required is minimal too. PTMS can be easily adapted and implemented in a home environment with very low cost.
(2) Instead of sending the health monitoring data to a centralized database in an ISP, health monitoring data is stored within the household. Only authorized caregivers can access the data. Privacy is better protected.
(3) The route from the sensor to server is much shorter. Data transmission is easier and more reliable. Communication bandwidth will not be occupied by meaningless sensing data continuously transmitted from sensors to the centralized database. Data integrity will be better preserved.
(4) This distributed structure can be adapted if a centralized database is needed. As shown in Figure 3, instead of passively waiting for data, the centralized database can actively request for data from DDSs in many households in a batch mode.

3. PTMS Applications

Equipped with different sensors, various PTMS applications have been developed, as described below:
(1) Environment Monitoring System

Equipped with sensors such as temperature sensor and humidity sensor, environment monitoring is the most typical application of PTMS. Figure 5 shows the VB interface developed for the Grand Palace Museum for temperature and humidity monitoring. On the left side of the screen, real time data from temperature and humidity sensors mounted on 4 different DDS can be monitored simultaneously. The user can also download historical data, and perform analyses such as calculating average temperature of the day, plot the temperature tendency of the week, etc.

![Figure 5. VB interface of environmental monitoring system](image)

(2) Daily Behavior Monitoring System

In the daily behavior monitoring system, we hope to be able to monitor the transition of a senior from a healthy, independent state into a state of incapacity and dependency, to recognize the change in pattern of daily activities, and to remind the caregivers to take early actions. Special-designed sensors detect activities such as eating, bathing, using the toilet, lying in bed, watching TV, etc. In this system, all sensors are embedded in the home
environment. The subjects may not be aware of the sensing actions taking place. Sensor signals are transmitted to the DDS through a battery-powered RF transmitter (Figure 6(a)). Besides the sensors fixed in the environment, a wearable accelerometer (Figure 6(b)) is under developed to recognize postural movements of the subjects when walking, sitting and standing or in postural transitions. Caregivers can use an interface similar to Figure 5 to read real-time sensor data, download historical data, perform various analyses, or set up event driven messages (GSM short message or email messages) once a sensor is activated.

Figure 6. (a) an RF transmitter and (b) a wearable accelerometer

(3) RFID-based PTMS

Figure 7 shows the structure of an entrance guard system designed for kindergartens. RFID (Radio Frequency IDentification) readers combined with optical switches are used as the sensors in the PTMS. The DDS is also connected to a SMS Module for Data Transmission (SMDT). When a child with an RFID tag passes through the entrance, DDS will identify the ID, and whether the child is entering or leaving, log the event in the DDS, and send an email or a GSM short message to notify the parents.
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Figure 7. Structure of an entrance guard system

(4) Sleep Quality Monitoring System

Figure 8 shows the structure of a sleep quality monitoring system. Special designed sensors are connected to the DDS to evaluate sleep quality from the subject’s external behaviors. The sleep quality sensors are designed in an unrestrained, non-conscious way, so that we can do long-term sleep quality monitoring in a home environment – on the subject’s own bed. From the external behavior signals (body temperature, body movement, breath, and snoring) instead of vital signs (e.g. brain waves), we can determine sleep quality indices such as the time in bed, sleeping time, latent period, times of awakening.
(5) Other vital sign sensors

Other vital sign sensors can be connected to the DDS. Figure 9 shows an ECG holter, which can measure and record ECG data in a small portable package. Real-time ECG data can be transmitted and displayed on a remote client PC through the Internet (Figure 10).

![Portable ECG holter](image)

**Figure 9. Portable ECG holter**
4. Telepresence Robot

Telepresence means visual, kinesthetic, tactile or other sensor feedback from the teleoperator to the human operator that is sufficient and properly displayed such that the human feels that he is present at the remote site, and that the teleoperator is an extension of his own body[3]. Figure 11 shows “Dr.Robot” developed by InTouch Health Inc, which is a good application example of a telepresence robot. The doctor can “drive this telepresence robot to patrol and check up on patients[4].
Aging is associated with an increased risk for isolation. We also designed a telepresence robot (Figure 12) to provide a new way of communication. Basically, it is a "mobile DDS", which integrates various sensors, a network IP camera with audio module, a wireless LAN AP, actuators, and batteries, altogether inside a vehicle. Users can control the telepresence robot from a remote client PC to move around. Two-audio and one-way video communication can be transmitted through the Internet. Any PTMS-related function can be carried out as well.

The telepresence also has the ability to perform fundamental autonomous behaviors while not being controlled, such as following a given track, detecting obstacles, and auto-charge at low battery capacity.
5. Future Work of PTMS

This paper presents an on-going project of a Portable Tele-homecare Monitoring System developed in GRC, YZU. Several PTMS applications are also demonstrated. Some of these applications have been tested in practical uses, proven to be complete, stable, and reliable in performance. Currently we are testing the existing applications, and expanding the applications. We are also applying for patents, Figure 13 shows the patent portfolio of PTM, and we are looking forward to collaborating with industries for commercialization of PTMS.
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Figure 12. Patens Portfolio of PTMS

Reference


