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# A real-time life-care monitoring framework: WarnRed hardware and software design

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**Abstract:** It is shown by many statistical studies that the senior population, especially in developed countries, is in an increasing trend. For many reasons they tend to have in-home health care providers. The recent studies on biomedical information management focused on remote health monitoring frameworks including heart rate monitoring systems, glucose measurements for diabetics, and remote monitoring EEG and ECG. The main purposes of these studies are timely response to emergency situations and ensuring that the person is in a stable condition. In this study, developed via a system-on-chip circuit, we process the data collected from subjects through a temperature sensor and blood pressure sensor. Data are submitted in real time via a wireless secure channel to medical experts. An easy-to-use software interface is also developed as part of the framework.

**Key words:** Telemedicine, remote monitoring interface, geriatric care, wireless sensor network

## 1. Introduction

Although we are living in the era of technologic advances, the rising elderly population, especially in the western countries, is a main concern of societies. This is depicted in Figure 1. Bloom et al. showed that this trend will continue in the future [1]. Therefore, individual life styles result in a lack of care providers for seniors.

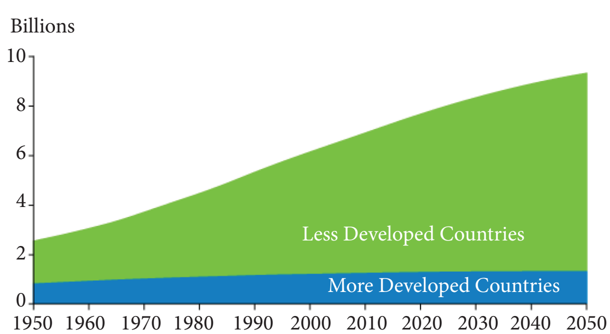


**Figure 1.** World population growth [2].

On the other hand, thanks to innovations in communication and computational fields, scientists use different techniques in telecare, telehealth, and telemedicine to support human health. In general, these techniques allow physicians and care providers to access and analyze real-time data collected from those subjects

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who stay at home. The advantages of these systems include not only timely responses to emergency cases but also reduced costs related to visiting physicians.

Health care studies, which first started in the psychiatric area via video conferences, make significant progress by means of transmission of various biomedical signs to care providers with fast-growing communication techniques. Particularly remarkable progress in wireless communication allows us to utilize the Internet effectively in health areas.

Wireless sensor networks such as wireless body sensor networks, ZigBee, Bluetooth, GSM networks, and wireless local area networks (WLANs) have considerable importance in wireless communication. They are typically used in telecare systems because of their advantages like ease of use, cheapness, and wide usage.

The developed framework, which is called WarnRed, is composed of two units, software and hardware. The hardware, developed using a system-on-chip (S-o-C) circuit, analyzes collected vital signs such as temperature and heartbeat data from a subject. The signs are then transmitted to a computer by a WLAN Ethernet device. There are two approaches that we can follow here. First, there might be a dedicated communication channel over a predefined IP. Assigning a private IP would provide security against DoS and network viruses. However, this solution comes with a disadvantage in that the host machine cannot reach a wide area network. Second, we can assign an IP address to the WLAN card to make it accessible through the Internet. The latter case would cause vulnerability in the network security, but this may be tolerated by using encryption algorithms such as WPA and WPA2 that exist in the WLAN card.

The software is a web page interface based on .NET and designed using MATLAB Builder NE and Web Figure features. Data submitted by the hardware unit can be viewed and interpreted both digitally and graphically by experts. MATLAB Web Figure allows results of the received data to be monitored in a web browser after being analyzed by MATLAB. The software of the framework is well designed so that operating personnel are not required to know any technical details of WarnRed.

### 1.1. Geriatric care basics: telehealth, telecare, telemedicine

Although there is no consensus on these terms, we follow the definitions published by the World Health Organization (WHO) in 2004 [3]. Accordingly, we explain telehealth, telecare, and telemedicine below.

#### 1.1.1. Telehealth

In a broad sense, telehealth covers infrastructure consisting of health support networks, biomedical education, workshops, and patient consultation utilizing information systems [4]. Likewise, training on remote monitoring health care systems can be delivered via telemedicine.

#### 1.1.2. Telecare

By definition, telecare is to provide personal health care by means of telecommunication [5]. Thus, it is a great plus for medical providers to use telecare to extend their services to patients. It was also shown that seniors opt to continue living in their own residences even after medical diagnoses [6].

In a historical perspective, today we are passing through a third era in telecare. At the beginning, around 1960, there were simple buttons and alarm systems [7], while the second generation introduced sensor-based systems [8]. Today more intelligent and capable devices are available to process data in diagnosis and monitoring [9].

### 1.1.3. Telemedicine

The first study in the literature of telemedicine was conducted by Einthoven in 1906. He succeeded in transmitting ECG signals over a phone line [10]. The WHO defined telemedicine as the practical usage of audio and visual data in health-related services. The key point in telemedicine is its usage in emergency cases, in which mortality rates are reduced significantly [11]. As per the recommendation of the US Food and Drug Administration, manufacturers are urged to design more convenient devices [12].

## 1.2. Wireless technologies in health care

WLAN (IEEE 802.11 b/g), Bluetooth (IEEE 802.11.5), ZigBee (IEEE 802.15.4), and GSM networks are among the wireless components used in health care systems. We show in the Table the wireless devices exploited in remote monitoring systems in terms of frequency band, band width, data transmission speed, multiple access method, and coverage range [13].

**Table.** Wireless technologies in health care.

| | MICS | WMTS | UWB IEEE (802.15.6) | IEEE (802.15.6) (ZigBee) | IEEE (802.15.6) (Bluetooth) | WLANs (802.11b/g) |
|---|---|---|---|---|---|---|
| Frequency band | 402–405 MHz | 608–614, 1395–1400, 1429–1432 MHz | 3–10 GHz | 2.4 GHz (868/915 MHz Eur./US) | 2.4 GHz | 2.4 GHz |
| Band width | 3 MHz | 6 MHz | >500 MHz | 5 MHz | 1 MHz | 20 MHz |
| Data transmission speed | 19 or 76 kbps | 76 kbps | 850 kbps to 20 Mbps | 250 kbps (2.4 GHz) | 721 kbps | >11 Mbps |
| Multiple access method | CSMA/CA, polling | CSMA/CA, polling | N/A | CSMA/CA | FHSS/GPSK | OFDMA, CSMA/CA |
| Transmission power | −16 dBm (25 μW) | ≥10 dBm and <1.8 dB | −41 dBm | 0 dBm | 4.20 dBm | 250 mW |
| Coverage range | 0–10 m | >100 m | 1.2 m | 0–10 m | 10, 100 m | 0–100 m |

Among many studies, Lee et al. suggested transmitting blood sugar and ECG signals over cellular networks and ZigBee devices [14]. In a similar study, ZigBee networks were utilized to store and analyze heartbeats, plethysmogram, and blood oxygenation [15]. In another study, ECG signals were monitored in a web-based graphical user interface. The data were stored in a MySQL database and scrutinized in a PDA. Portable ECG sensors were paired with ZigBee-based receivers [16]. A different study conducted by Landolsi et al. recorded glucose level, heartbeat rate, and pulse oximetry data in an embedded system that communicates through a cellular network. The E-Med interface was used to receive the data. Received data were monitored with the MultiMon system and stored [17]. In another paper, Bluetooth was used to convey biomedical signals such as pulse oximetry, blood pressure, and ECG [18]. Yuce developed a health monitor system that inspects EKG, EEG, EMG, and pulse data through MICS and WMTS [19].

As seen in the Table, WLANs have big bandwidth and can accommodate high-speed data transfer. Therefore, they can be used for health care monitoring applications. In fact, many health care monitoring applications using WLANs have already been developed. One of them is the miTag system [20]. It transfers all health care monitoring data to the Internet. Another example is the BlueCode system developed at Harvard University. It collects pulse oximetry and ECG data via a wireless sensor network and uploads them to the Internet [21]. Furthermore, PDAs can be used to obtain data and respond properly in a system of insulin pump and glucose sensor control [22].

In telemedicine applications, security is a subject of great importance. In wireless communication devices in particular, the data should be protected against security breaches. This is a two-step process: user information should be protected, and protected data should be authenticated between the client and server. With the exception of a few studies, data encryption is an obligation in all remote health monitoring applications [23–25]. Although security brings many benefits to the systems, extra computational time is inevitable because of additional algorithms.

## 2. Related works

Both communication and S-o-C developments contribute significantly to remote health care systems. Today it is possible to provide various health services thanks to S-o-C-based wearable body monitoring systems.

The first steps in these studies were more focused on detection of emergency situations [19,26]. A few other works provided health care services such as continuous monitoring, distance-based controlling medical devices, patients' data, and emergency communications [27,28]. Particular studies based on live broadcasting are used to alert medical professionals about emergency situations [29–31].

Recent efforts are especially focused on how to make telemedicine systems compact, the means of low energy consumption, the low costs, and the ergonomics of devices [32–36]. The response time in telemedicine is also of paramount importance. For instance, in the case of a heart attack or a sudden fall, the warning should be transmitted to second parties immediately [37].

## 3. An overview of the study

The developed telemedicine framework is depicted in Figure 2. This work is conducted in three steps: acquisition of vital signals via a S-o-C circuit, transmission of the signals over a WLAN, and assessment of the data in a web-based GUI.

WarnRed is used to process vital signals obtained from subjects such as temperature and blood pressure. As soon as the signals are collected, they are transmitted to corresponding parties to be analyzed. There are two ways to transmit the data: through the Internet or the access point, as shown in Figure 2. In the case of usage of the access point, the communication is conducted over a dedicated line. Medical experts assess the data after transmission is completed. Since WarnRed is a web-based software, experts can access the GUI via various devices such as a computer, a tablet PC, or a smartphone.

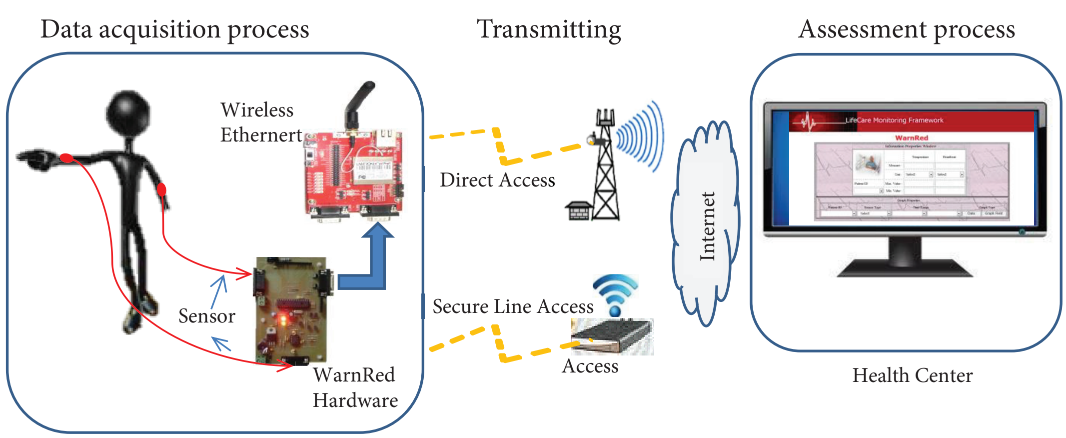


**Figure 2.** Schematic representation of the study.

## 4. The WarnRed hardware and software

The motivation of this study is that operating a telemedicine system should be easy and should require no technical knowledge. WarnRed is designed to be a self-driven system with no user intervention.

### 4.1. Hardware component

The hardware unit is composed of two parts: the controller unit sensing and analyzing the vital signals, and the wireless transmission unit. A block diagram and picture of the system are seen in Figures 3 and 4, respectively.

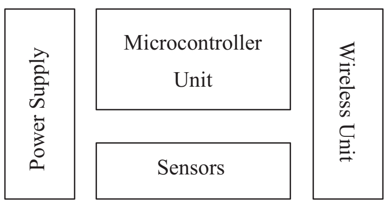


**Figure 3.** Block diagram of the system.

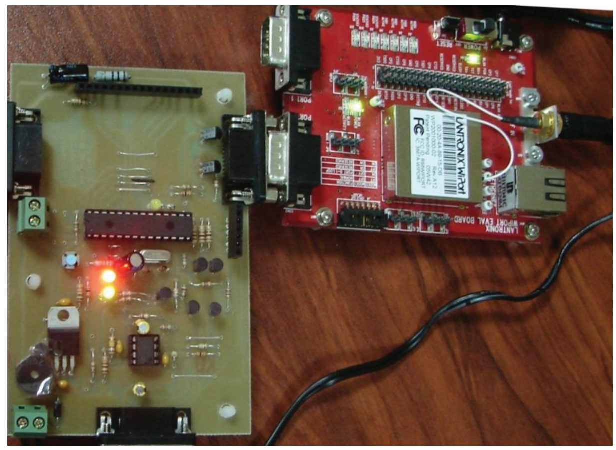

**Figure 4.** Picture of the hardware unit.

The hardware unit is designed as a prototype that has bigger dimensions than the applicable unit in daily life. Length and width of the controller unit of the prototype are 10.5 cm and 5.5 cm, respectively. In spite of the fact that the prototype has large dimensions for use in daily life, its dimensions can be reduced to be at least 3 times smaller.

The controller unit in the hardware has an $SpO_2$ pulse oximeter probe, an LM358P as a low-pass filter, and a PIC 18F252 as a microcontroller with 32 KB code and 1536 byte data memory. The data collected from the sensors are transmitted by the microcontroller via a WLAN. A WiPort Ethernet card is used as a wireless transmitter, which is, in fact, a wireless server. The block diagram given in Figure 5 standardizes data into IEEE 802.11b.

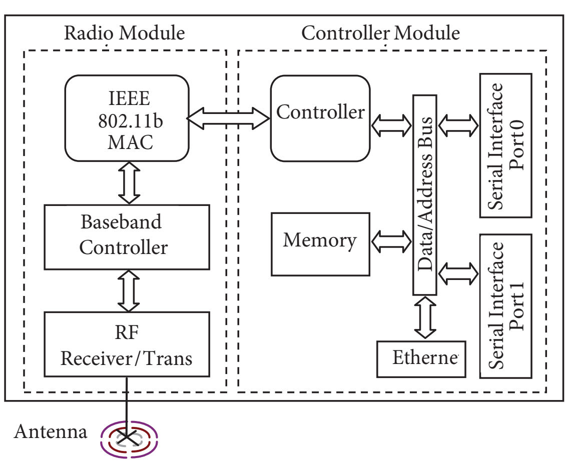


**Figure 5.** Block diagram of WiPort Wireless Ethernet.

### 4.2. Software implementation

The software was designed by using MATLAB [38], and it has variety of features such as analysis toolboxes, strong computational capabilities, and graphic abilities. The Web Figure feature enables analysis of a 3-D graph using any device that has a web browser. The collected data are stored in a Microsoft Access database. Stored data are then displayed as a graph by Web Figure. The flowchart of the software is shown in Figure 6.

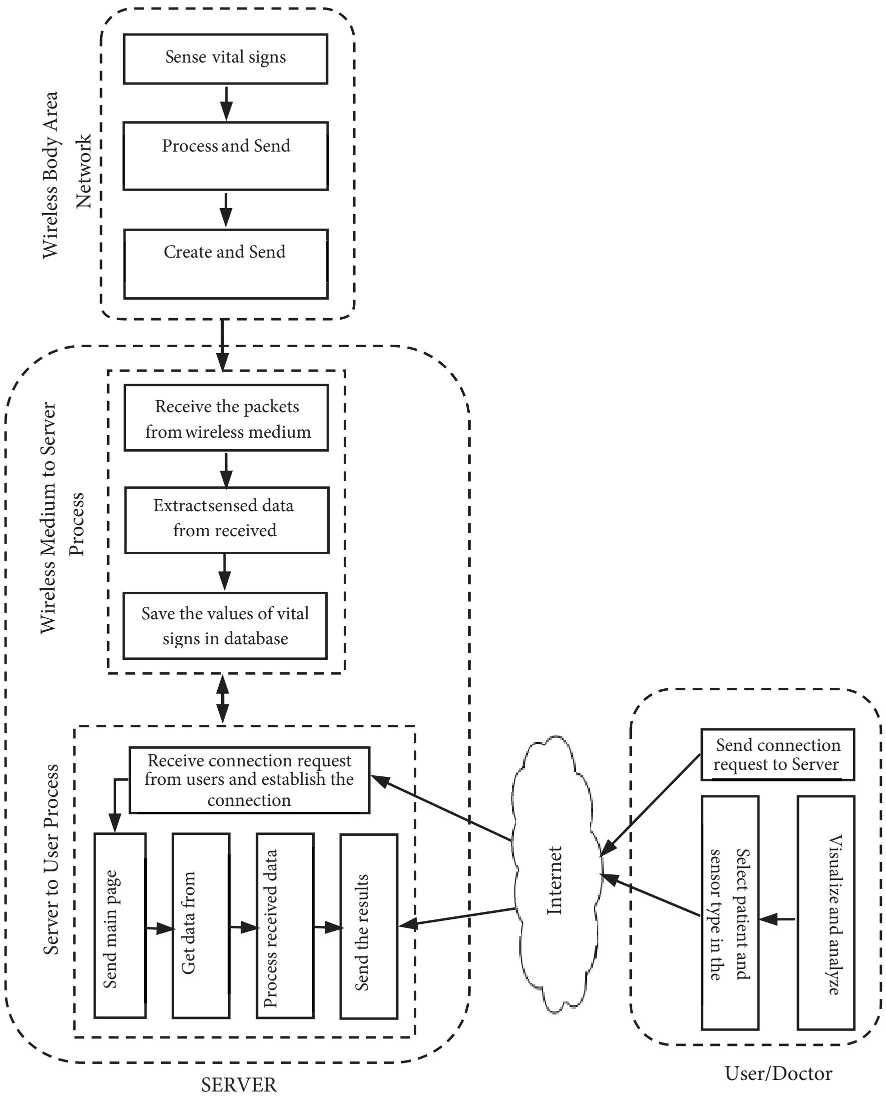


**Figure 6.** Flowchart of the software.

Figure 7 shows the main page of the software, which consists of two parts: the information properties window and graph properties.

As shown in Figure 7, the patient ID is chosen from the database. Afterwards, the sensor type is specified, such as temperature or heartbeat rate. Defined data are imported by the 'Data' button to the 'Information Properties Window' data field. Additionally, the specialist can define Max and Min values for temperature and heartbeat rate (Figure 8). The software will send a warning message to the specialist when the data increase over the Max or decreases under the Min.

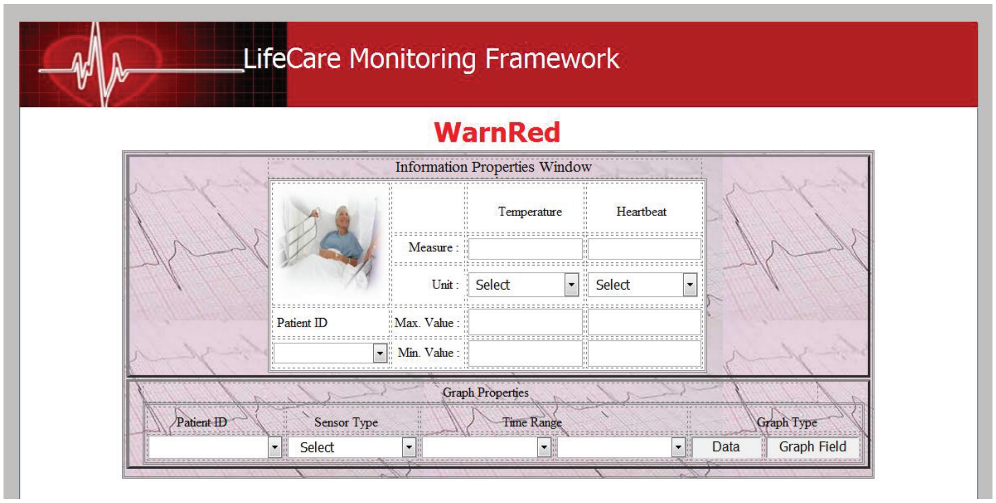


**Figure 7.** Main window of user interface.

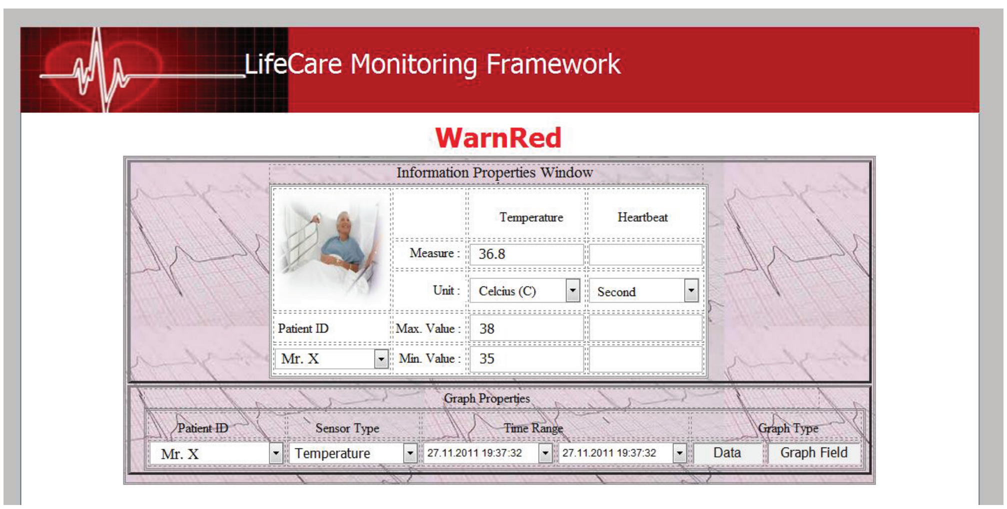


**Figure 8.** Defining sensor type, time range, and Max and Min values.

The graph of the patient's data sensor type and the time range are defined respectively. The graph is displayed in the 'Graph Field' by clicking the 'Graph Field' button (Figure 8). Figure 9 shows an example of how to choose the data and how to draw a graph of the data between certain dates.

In addition, the software allows the specialists to average the data. In Figure 10, the graph displays the average of temperature and heartbeat rates between '27.11.2011 19:37:35' and '27.11.2011 19:38.8'. The graph in Figure 11 shows temperature and heartbeat rate together. In the example, the mean temperature is 36.67 $^\circ$C and the mean heartbeat rate is 84.06/min.

The collected data can be saved in the software. In this manner, specialists have an archive for each patient. As shown in Figure 11, the data can be saved with the 'Save' button. The software saves temperature and heart beat data in .txt format.

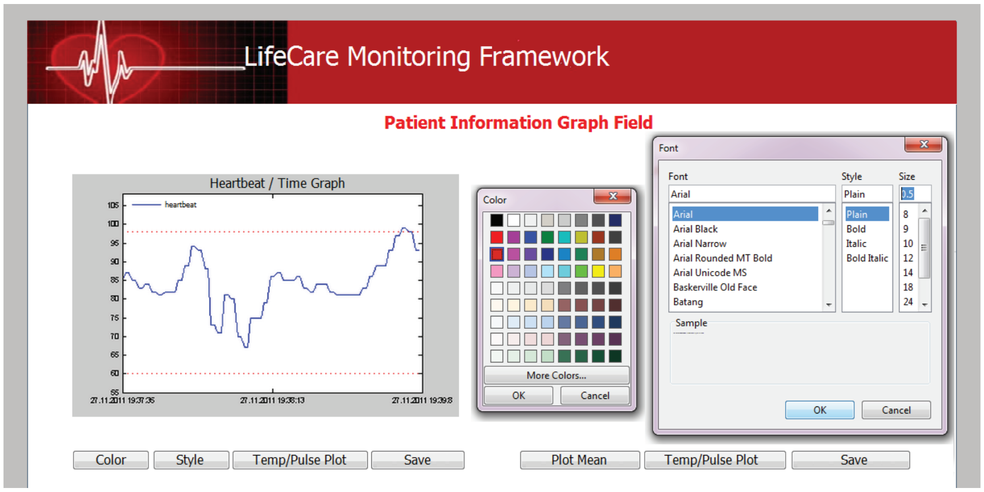


**Figure 9.** Plot of heartbeat rate.

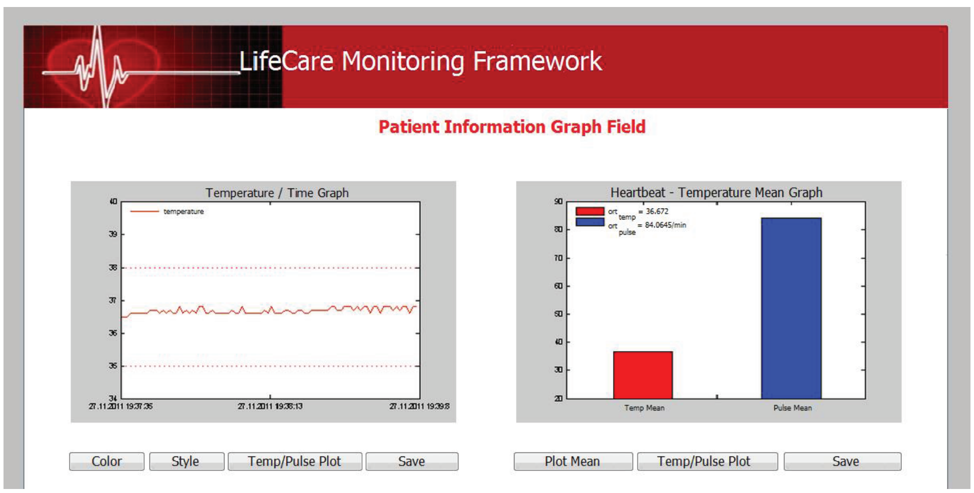


**Figure 10.** Mean of the temperature and heartbeat rate between certain dates.

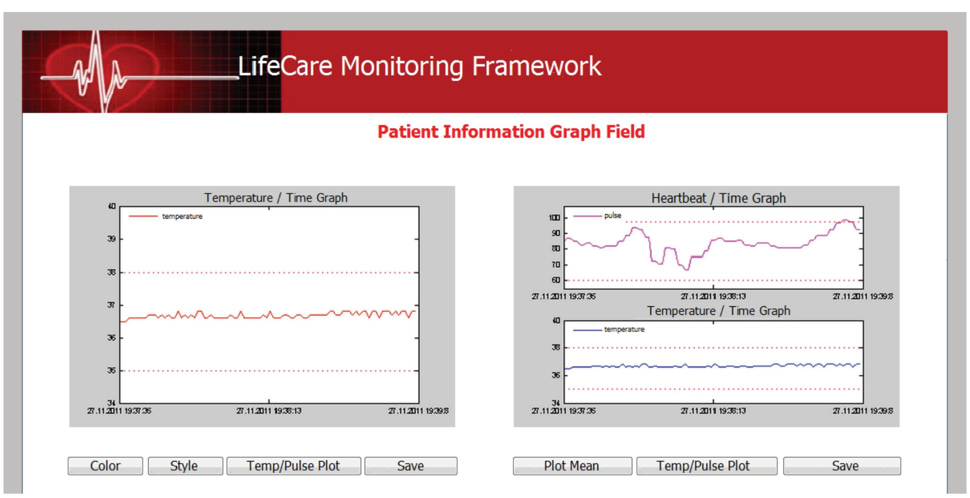


**Figure 11.** Plot of temperature and heartbeat data between certain dates.

## 5. Conclusions

In the last decade, the growing senior population tends to have in-home health care providers because of individual life styles. In this study, a new health care system, called WarnRed, is proposed to follow the medical conditions of the senior population. WarnRed is a MATLAB-based wireless health care system that can be controlled over the Internet.

The WarnRed framework includes two parts: a hardware unit and software. In the hardware part, S-o-C technology is used to develop the circuit, which can sense heartbeat rate and temperature. The software part is designed using a .NET platform such as C# for web interface design, MATLAB Web Figure for graph analysis, and Microsoft Access for database processing. The software is easy to use and health experts can use it with no technical difficulties. The Web Figure feature provides an especially significant advantage to users who need detailed analysis of signals.

The WarnRed framework provides some significant benefits, as follows:

- Wireless Ethernet technology has advantages such as low cost and wide usage.
- The PIC microcontroller-based hardware unit has low cost, low power consumption, and high measurement accuracy.
- The Web Figure feature provides more visualization and flexibility.
- The user does not need MATLAB software to use the WarnRed software since an executable version is also provided.

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