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HealthFace: A web-based remote monitoring interface for medical healthcare systems based on a wireless body area sensor network

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Abstract

The wireless body area sensor network (WBASN) is a type of wireless sensor network. The wireless sensor nodes in a WBASN are placed on, near, or within a human body. In a medical healthcare system, WBASNs continuously provide healthcare monitoring, especially of elderly or ill people, wherever the patient goes. Wireless nodes sense and process human vital signs such as heart rate, blood pressure, body temperature, and respiration. They then send collected data to a medical center via a base station in order for medical professionals to monitor the patient's health. In the medical center, doctors and caregivers need monitoring systems or interfaces to process, analyze, and visualize the received data from WBASN-based systems. In this paper, we present a web-based remote monitoring interface, HealthFace, for medical healthcare systems based on a WBASN. Users can easily access the developed HealthFace via any Internet-connected device, such as a PC, PDA, laptop, or cell phone, without needing any special software or programs except for a web browser. In addition, the implemented HealthFace presents several features, including recording, displaying, and analyzing collected data from the sensor nodes using MATLAB Builder NE with Web Figure. Web Figure enables users to utilize 3-dimensional view, zoom, and movement functions.

Key Words: *Wireless body area sensor networks (WBASN), telemedicine, remote monitoring interface, HealthFace*

1. Introduction

Recently, the use of wireless body area sensor networks (WBASNs), a growing research area, has increased in medical healthcare applications. WBASNs provide healthcare monitoring, especially for the elderly, infants, and chronically ill people. Generally, a WBASN consists of several wireless sensor and actuator nodes placed

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on, near, or in a human body. The WBASN nodes sense and process vital signs (blood pressure, blood flow, body temperature, pulse oximetry, electrocardiography, etc.) acquired from the human body. They then send the collected data to a medical center via a network coordinator (base station) so that doctors or caregivers can monitor the patient's health remotely. Medical professionals can easily describe the health of patients using received data from a WBASN [1-5]. Therefore, the doctors or caregivers need useful remote monitoring systems or interfaces to process, analyze, and collect the data sent to the medical center from the WBASN. They can thus easily monitor the healthcare of their patients using the remote monitoring systems or interfaces. Remote monitoring systems provide several benefits, such as identifying emergency conditions for patients, producing alerts, and allowing alerts to be accessed using mobile devices. In addition, employing WBASN-based systems decreases the workload, enhances the efficiency of medical personnel, and improves the comfort of patients [5].

This paper presents a web-based remote monitoring interface, called HealthFace, using MATLAB Builder NE with Web Figure for WBASN-based medical healthcare systems in order to monitor the medical status of patients and the elderly. Users can easily access the developed interface via any device, such as a PC, laptop, PDA, or mobile phone connected to the Internet, without needing any special software or programs except for a web browser. The implemented HealthFace also provides several features, including the ability to record, analyze, and display collected data from sensor nodes. In addition, Web Figure enables beneficial visualization with 3-dimensional view, zoom, and movement for users.

In order to demonstrate the usage of the developed interface, we designed a WBASN using Crossbow MICAz motes and MDA300CA data acquisition boards. We examined 3 measurements, temperature, humidity, and heart beat rate, in the WBASN.

2. Related works

There are many WBASN-based medical healthcare applications in the literature for monitoring the medical status of patients, especially the elderly and chronically ill people. The systems in most of these works widely monitor vital signs such as heart rate, electrocardiograph (ECG) signals, blood pressure, pulse oximetry, body temperature, and respiratory rates from the human body. Yuce et al. [6,7] presented a multipatient monitoring system with a wireless sensor network. They used their developed hardware based on a PIC microcontroller, which senses only temperature and pulse oximetry, and a software platform. CodeBlue [8,9] was a project developed at Harvard University. It consists of 2 stages: hardware and software. The hardware part of CodeBlue includes a pulse oximeter, a 2-lead ECG, and a motion analysis sensor board based on a Crossbow mote. The software platform provides communication among wireless sensor nodes. Navarro et al. [10] developed a health monitoring system, Medical MoteCare, based on MICAz motes including a pulse oximeter, thermometer, and light sensor. The Medical MoteCare system utilizes CodeBlue software. LifeGuard [11,12] was designed to monitor vital signs including ECG signals, respiration, pulse oximetry, and blood pressure, primarily for astronauts. It employed Bluetooth for wireless communication between the base station and sensor hardware. Further examples of such related works can be found in the literature. A survey of wireless sensor networks for medical healthcare systems is available in [13]. In addition, Pantelopoulos and Bourbakis presented an overview of proposed and used wearable sensor-based systems for health monitoring [14].

Compared to the applications mentioned above, HealthFace has 2 important properties. First, it runs on standard server services without requiring any other software on the server. Users can only access it using a web browser. Therefore, HealthFace enables a lower response time because it does not require the downloading and

installation of any programs. As a result, it creates a smaller workload and it runs faster. Second, HealthFace uses MATLAB Builder NE, which provides a highly flexible environment and visualization means including zoom and movement functions. MATLAB is a widely used tool in engineering applications.

3. The proposed WBASN-based system architecture for HealthFace

The proposed system architecture for usage of HealthFace in medical healthcare systems depends on the WBASN shown in Figure 1. The proposed system includes 3 tiers: a WBASN, a base station or network coordinator, and a medical center, respectively.

The sensor network comprises multiple interconnected sensors/actuator nodes placed on, near, or in a human body. The sensor nodes sense and process vital signs such as ECG signals, blood pressure, body heat, and respiration. They then send the sensed/processed vital signs through a base station to the medical center for monitoring by medical professionals. A cell phone, PDA, or computer can be used as a base station. The base station is a bridge or a network coordinator between the sensor network and the medical center. It carries out several different tasks. For example, it collects, analyzes, and visualizes obtained signals from the sensor nodes. It transmits received data from the sensors to the medical center. The base station utilizes an Internet connection over WiFi/GPRS/WWAN to communicate with the medical center. At the medical center, the HealthFace software records, reports, and monitors the received data from the patient. The doctors or caregivers analyze patient data using the software. If there is an abnormal situation, the software gives an alert and the medical center staff intervenes for the patient via emergency services or sensor actuators/devices such as insulin injection [4]. The users can easily access the developed HealthFace on a server in the medical center by using any device, such as a PC, laptop, PDA, or mobile phone connected to the Internet, without needing any particular software or program except for a web browser.

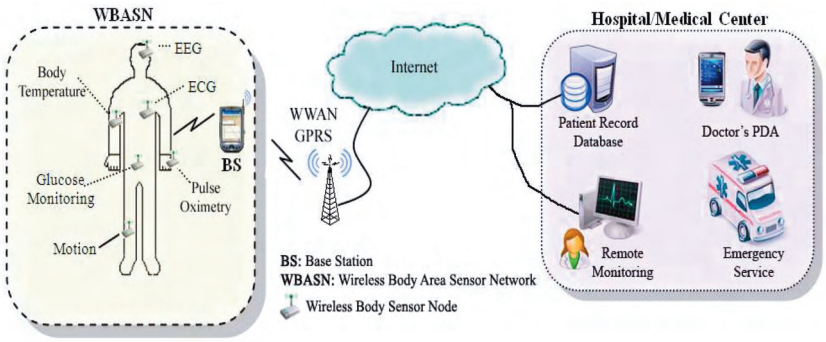

Figure 1. The proposed system architecture for HealthFace.

4. HealthFace: A web-based remote monitoring interface for medical healthcare systems based on wireless body area sensor network

In this section, we present the developed HealthFace using MATLAB Builder NE with Web Figure and .Net technology for medical healthcare systems based on a WBASN. Its usage is also illustrated through application examples. The WBASN consists of MICAz nodes equipped with a Crossbow MTS400 sensor board, as shown in Figure 2. The MICAz nodes have an ATmega128L microcontroller including a 128-KB code, a 4-KB data

memory, and a Chipcon CC420 RF transmitter based on IEEE 802.15.4. The MTS400 board senses temperature, light, pressure, humidity, and acceleration in the deployed environment. In order to read external data from the designed heart beat monitor circuit, we used an MDA300CA data acquisition board, which provides a connection between the external circuit and the MICAz node. In addition, an MIB520CA interface is the base station, connecting a computer with the wireless sensor nodes through USB.

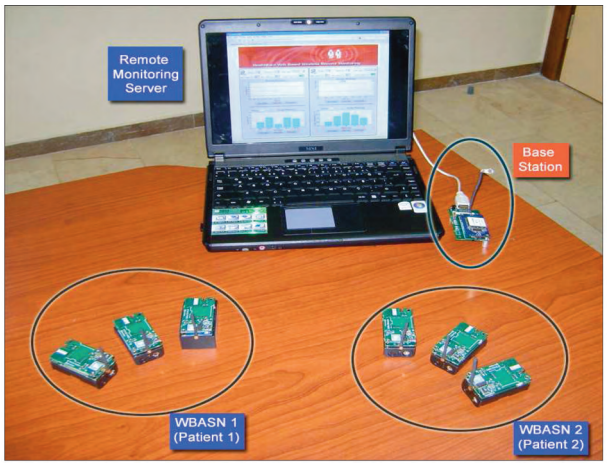

Figure 2. The implemented wireless body area sensor network.

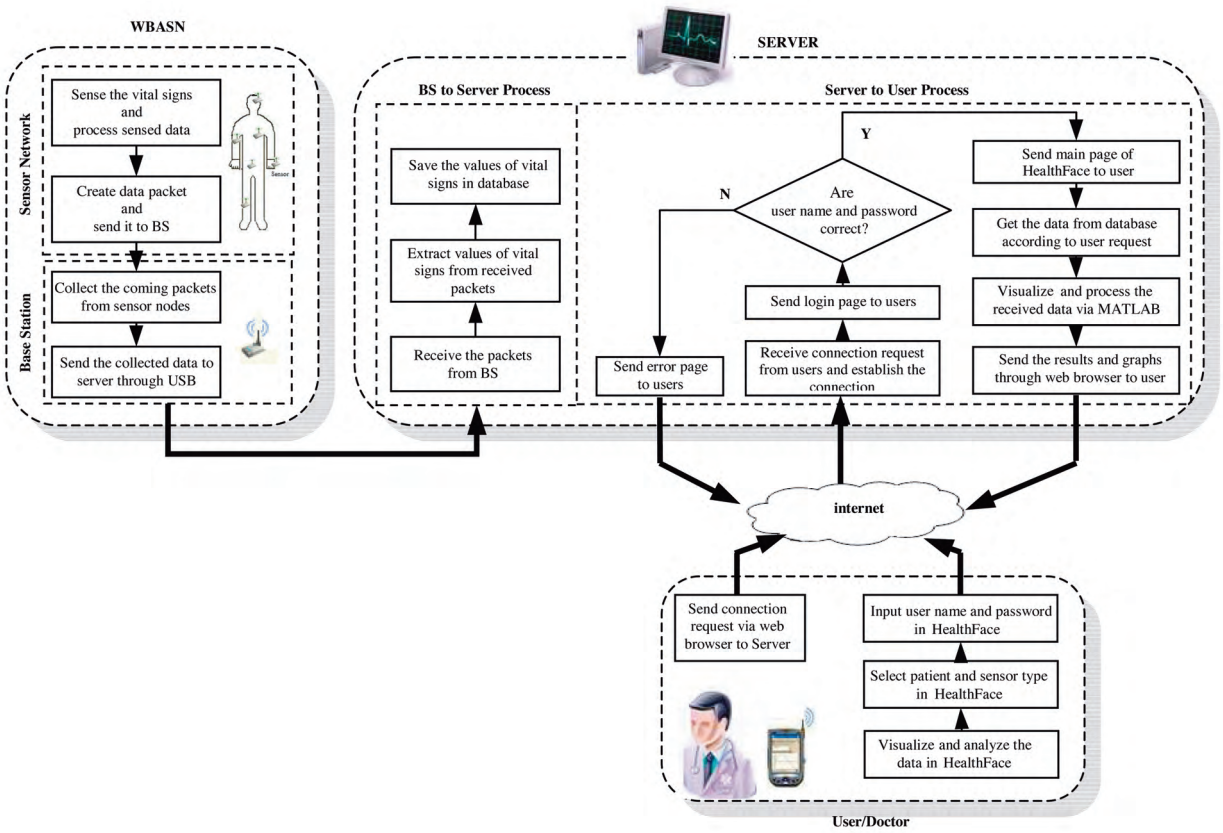

Figure 3. Flowchart of the implemented system architecture for HealthFace.

MATLAB is a widely used tool in engineering and research areas. MATLAB enables many additional features, such as a large library, analysis tools, and powerful numeric computation capability. In MATLAB builder NE, the Web Figure element allows the showing of MATLAB figures on a web page and visualizations such as 3-dimensional, zoom, and movement in figures. With this module, the user can easily manipulate visual applications using only a web browser over the Internet without using MATLAB or any other special program [15-17].

The implemented system's simplified flowchart is illustrated in Figure 3.

In order to prevent unauthorized access, we designed a HealthFace login page including username/password entrance, as shown in Figure 4. As a result, HealthFace can be used by only permitted users.

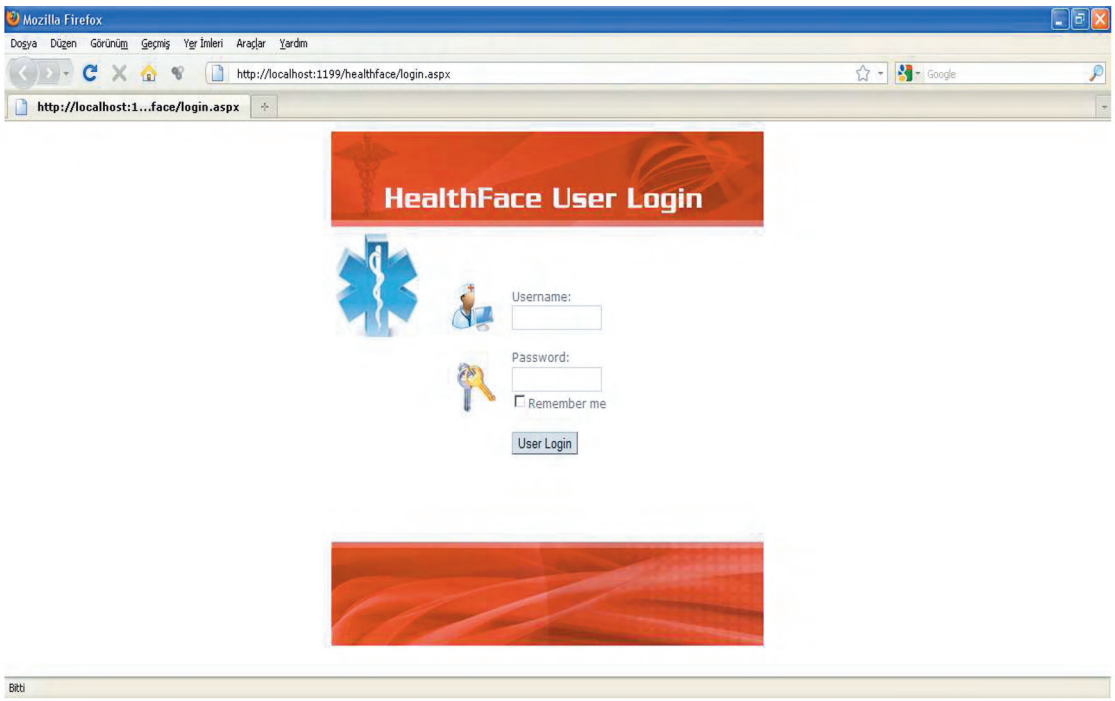

Figure 4. Login screen of the designed HealthFace.

After entering the username and password correctly, the main HealthFace interface appears, as shown in Figure 5. Users process and analyze data acquired from the WBASN-based medical healthcare system via HealthFace.

As seen in Figure. 5, HealthFace allows for the monitoring of received data from 2 different WBASN sensor nodes as real-time information and averages simultaneously. Hence, HealthFace consists of 2 sides. In each side of HealthFace, users can choose patient, sensor, and data types belonging to the selected sensor. The user can observe the current value of received data from the selected sensor in an input box. In addition, it allows calculation of a maximum value and a minimum value related to the received data from the selected sensor. These values are placed at the top of the page. If the received/monitored data from the selected sensor exceeds the maximum value or falls below the minimum value, HealthFace declares an emergency case. When an emergency circumstance occurs, HealthFace gives an alarm and sends a warning message to doctors or caregivers automatically. For example, the maximum value, the minimum value, and the current value of the sensed body temperature are 39 °C, 35 °C, and 36.3 °C, respectively.

There are 2 graphics on each side of HealthFace. The first graphic shows real-time values of the received data from the selected sensor as a function of time. Maximum and minimum values are shown as dashed lines in same graphic. The second graphic, which is located under the first, displays average values belonging to the selected sensor as a bar graph according to the input value and unit (daily, weekly, monthly). For example, the second graphic on the right side in Figure 5 shows the average value of the sensed body temperature as a function of the last 5 weeks. This feature provides doctors with useful information about patients.

Additional important features of HealthFace are the ability to save graphics and sensed data, and then print them. These properties make it possible to report on patient health information. Thus, medical professionals can detect vital sign variations with long-term health monitoring. In Figure 5, the "Save Graphic" button saves the produced graphic as a PNG or JPEG file, and the "Save Data" button saves the received data from the selected WBASN sensor node. Users can also print the graphic with the "Print Graphic" button.

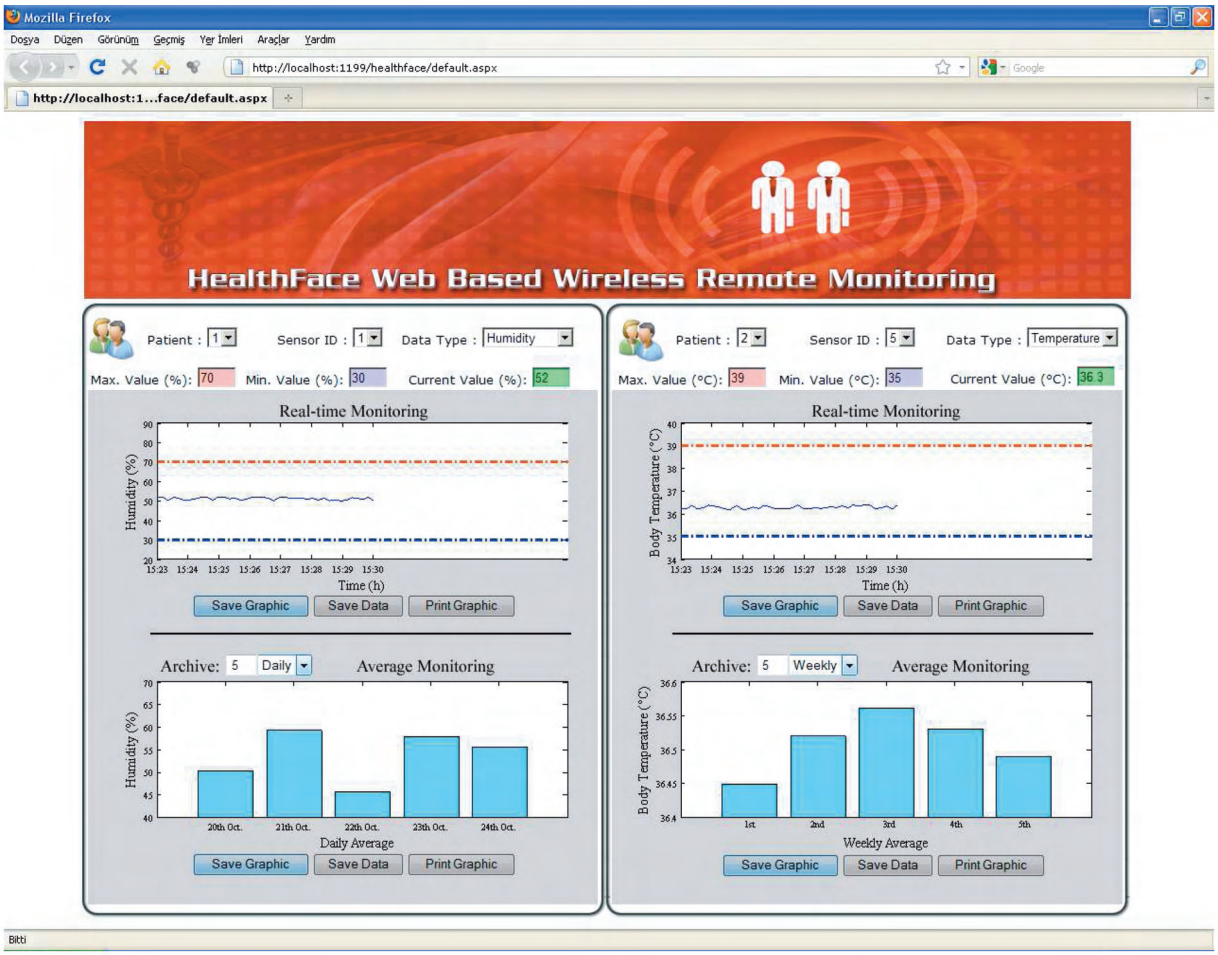

Figure 5. Usage of the designed HealthFace.

In HealthFace, the features of MATLAB Web Figure, including 3-dimensional view, zoom, and movement within the graphic, are made available when the cursor is over the graphic area. In Figure 6, the first graphic of patient 2 (on the right side) shows the use of the zoom attribute. Users may zoom in and out to analyze the graphics easily.

Figure 6. The zoom feature of Web Figure in HealthFace.

Figure 7 shows the designed heart beat monitor circuit and connection with a MICAz mote. The heart beat monitor circuit consists of a SpO_2 pulse oximeter probe, an LM 358 op-amp as a low-pass filter and signal amplifier, a microcontroller (16F628A), and a 2-row, 16-character illuminated LCD display with a blue background to show the heart beat rate and produce an analog signal according to the patient's pulse. Software loaded in the microcontroller calculates the heart beat period in milliseconds. It easily measures spent time between 2 rising edges of the heart beat signal, then calculates the heart beat rate in beats per minutes and drives the LCD display to show the heart beat. At the same time, the microcontroller first generates a DC level analog signal using the pulse width modulation method to drive the analog input (A0) of the MDA300CA. Thus, the DC level of the generated analog signal represents the patient's heart beat rate and is directly transmitted to the WBASN using the MDA300CA analog and digital data acquisition board. More information about the sensor and data acquisition board is given in [18]. In addition, example applications of MDA300CA can be seen in [19].

Results obtained from the heart beat monitor for 2 different patients can be seen in Figure 8. The heart beat rate can be changed according to some physical parameters, such as the patient's body mass, age, or physical activity. In real-time monitoring graphs, average heart beat rates for patient 1 and patient 2 are measured as approximately 80 and 85, respectively. However, if doctors/caregivers want to review recent values belonging to a specific patient, they can easily look at archived data as bar graphs for daily and weekly periods.

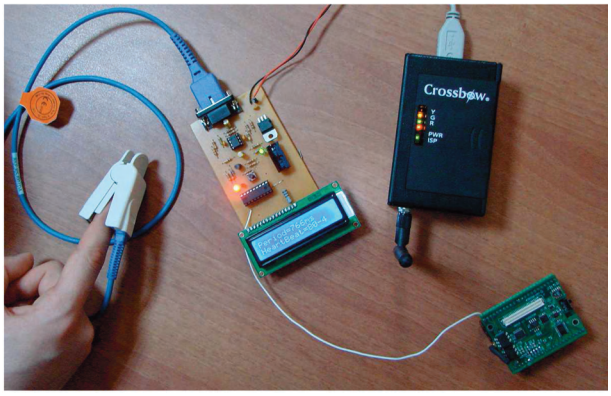

Figure 7. The designed heart beat monitor.

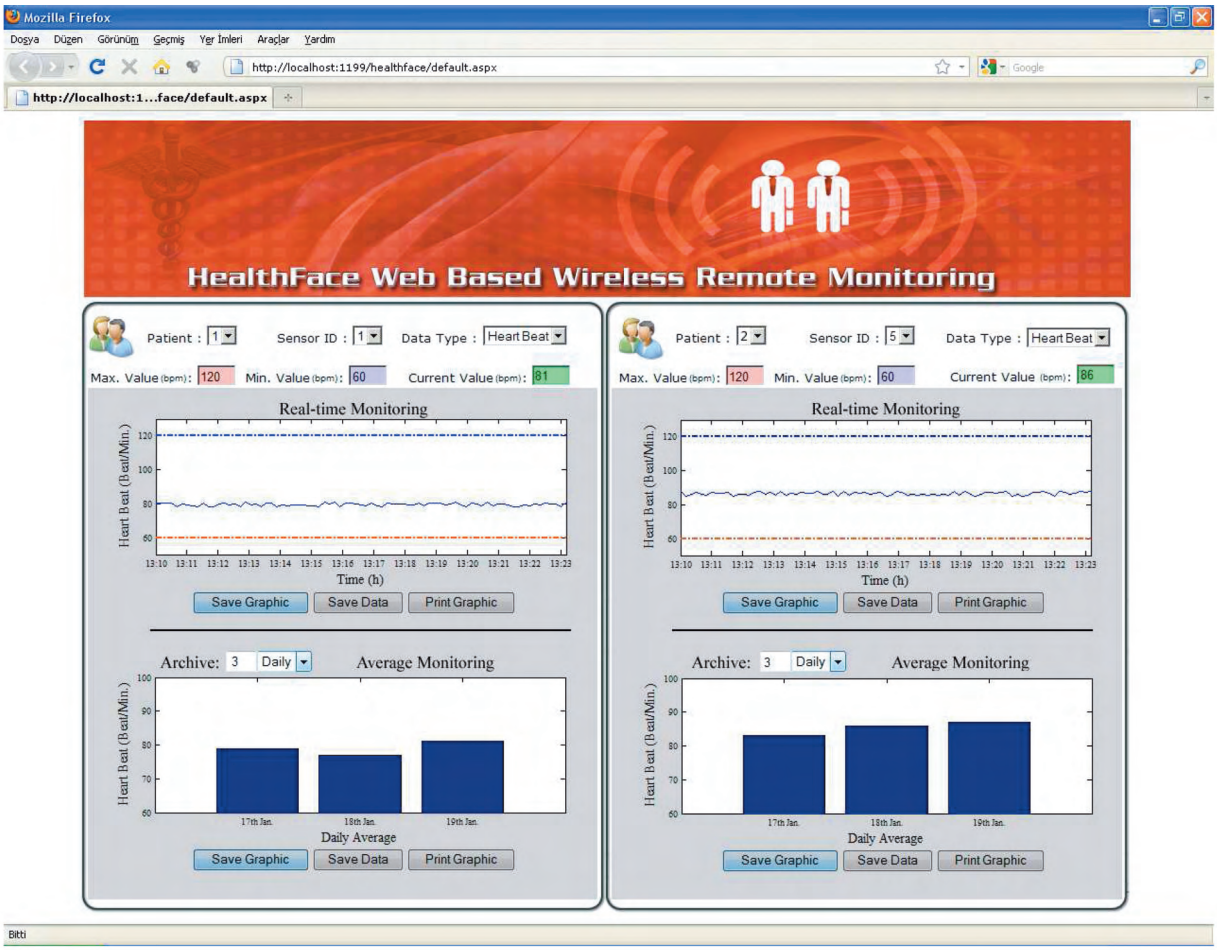

Figure 8. The measurement of heart beat in HealthFace.

5. Conclusion

Use of WBASNs in medical healthcare applications is increasing these days. This paper presents a developed program, HealthFace, to monitor the health status of patients or the elderly. HealthFace is a web-based remote

health monitoring interface using the MATLAB Builder NE with Web Figure and .Net technology for medical healthcare systems based on a WBASN. In this work, the WBASN consisted of MICAz nodes, including MTS400 and MDA300CA sensor boards. We have shown the measurement of temperature, humidity, and heart beat rate values using the developed hardware and software.

HealthFace has 2 important features. First, users can access HealthFace with only a web browser, not needing any particular programs due to use of server technology with MATLAB Builder NE. Second, it enables high visibility, ease of use, and flexibility for users by employing Web Figure. Web Figure presents useful attributes such as 3-dimensional viewing, zoom, and movement functions to analyze the graphics. HealthFace also provides users with the ability to save data and graphics. HealthFace was designed for general aims and can accordingly be used in many different mote-based medical healthcare applications with small changes.

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