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Remote Monitoring of Patients and Emergency Notification System for U-Healthcare

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Abstract

This study proposes a remote monitoring of patients and emergency notification system with a camera and pulse wave sensor for U-Healthcare. The proposed system is a server client model based U-Healthcare system which consists of wireless clients that have micro-controller, embedded-board for patient status monitoring and a remote management server. The remote management server observes the change of pulse wave data individually in real-time sent from the clients that is to be remote-monitored based on the pulse wave data stored by users and divides them into caution section and emergency section. When the pulse wave data of a user enters an emergency situation, the administrator can make a decision based on the real-time image information and pulse rate variability. When the status of the monitored patient enters the emergency section, the proposed U-healthcare system notifies the administrator and relevant institutions. An experiment was conducted to demonstrate the pulse wave recognition of the proposed system.

Key words: Embedded System, Pulse Rate Monitoring, Server-Client Communication, Emergency Detection and Notification

1. INTRODUCTION

In the past, diagnosis and treatment of a disease was only possible in medical institutions but the recent development of IT technology is integrating the systems of other relevant technologies. Medical technology is also combined with IT technology, changing the paradigm so that medical service can be provided in everyday life [1].

As opposed to passive medical service that alleviates and treats symptoms of patients, U-Healthcare service provides active form of medical service that improves the health of the general public, prevents diseases, and quickly detects an emergency situation [2-3].

The main elements of U-Healthcare include sensing that measures bio-signals regarding physical and chemical changes in a human body; monitoring that processes the measured bio-signals and displays the analysis results; analysis that receives the data measured over a long time and produces health index from the accumulated data; and feedback that gives advices on health status and responses to emergency situation [4].

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2. Trend and Cases of U-Healthcare

The U-Healthcare market is growing day by day. The global healthcare market is projected to reach 6,298.9 billion USD by 2020, and the average annual growth rate is likely to be maintained at over 25%.

Apart from the economic reason, developed countries are actively promoting U-Healthcare projects because of the increasing national demand for improved medical service as the income level of those countries steadily rose. Also, due to the aging societies around the world, the medical expenses are rapidly rising, and a new medical service system based on IT is expected to solve this problem.

The direction of standardization is also an issue. At the moment, eight working groups are acting as a technology committee of International Organization for Standardization (ISO). They are mostly developing standards for interconnection and compatibility between medical equipment and digitalization of medical records. Also, standardization of framework, transmission and data to enable data transmission and exchange between different medical devices is in progress [5-6].

The representative U-Healthcare service structure has been proposed by GE as shown in following Figure 1 [7].

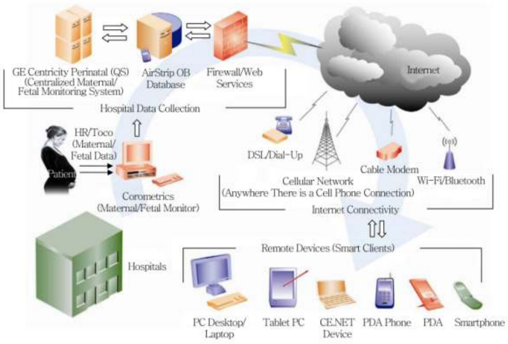

Fig. 1. U-Healthcare Service Structure of GE

3. Remote Monitoring of Patients and Emergency Notification System

A. Hardware Composition

In the proposed system, to collect main information to understand the status of a user in a remote environment, a pulse wave sensor was used as a main data collector in a client device. A pulse wave sensor can measure pulse rate variability to check abnormalities of the body and prognosis of a disease by using the variability of pulse rate, which is one of the data obtained from the time series of pulse wave.

Also, a client has a webcam that can provide a remote visual scene of a patient for the administrator to check the status of a user and an electrostatic switch for the user to notify an emergency situation.

As shown in Figure 2, client integrates the information transmitted from each sensing device using an embedded board. Embedded board determines prognosis and emergency by communicating with the management server.

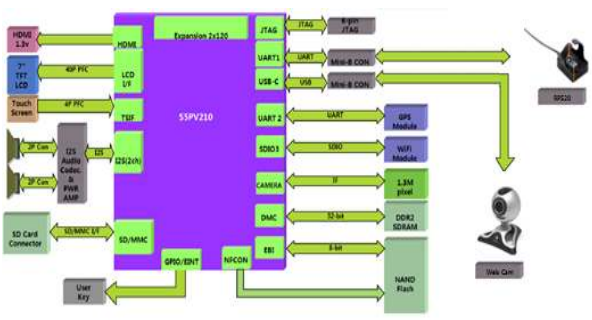

Fig. 2. Embedded board-based hardware block

B. Measuring Pulse Rate Variability

In this system, pulse rate variability is used for collecting the data for patients' status. The wave form of pulse wave reflects kinematic characteristics of blood and blood vessel caused by heartbeat.

As a method for pulse rate detection, as shown in Figure 3, the quantity of light reflected after lighting continuous light from a sensor on a skin cell is collected with a photodiode. Photodiode produces current in proportion to the amount of incident light and converts the current to voltage. The output of I-V converter used here is used as input of LED driver circuit and signal amplifying circuit. The latter performs AC amplification of the input signal. The amplified signal is outputted as a pulse wave signal (PPG) after applying LPF.

LED driver circuit, after receiving control voltage (Vc) and the output of I-V converter, outputs LED current so that the two voltages have the same size. Then, as Vc increases, so do LED driver and wave form signal, and the output signals directly provided from the output terminal of the operating amplifier.

The LED control voltage is transferred to the input terminal of the high input impedance operational amplifier through pull-down resistance at 10kΩ. Through this process, the ADC value that measured the real-time user data received through a pulse wave sensor is outputted in a graph. Finally, by comparing with DB that collected normal pulse rates of the server user, the current status of the user can be measured with high reliability. Figure 4 is an output of the finally received information presented in a graph.

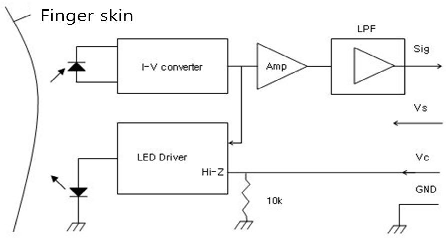

Fig. 3. Block of pulse wave sensor

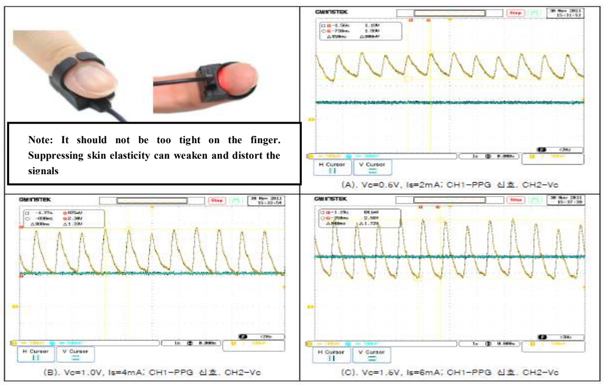

Fig. 4. A finger wearing the pulse wave sensor and pulse wave charts

C. Wireless Network Communication

To transmit the user data collected from client hardware to the server, a server-client socket communication was designed and implemented by using TCP socket in C# and .Net Framework 2.0 environment. The outline of TCP

Socket is shown in Figure 5. For data transmission between server and clients, a socket is created using the socket function, for server and client, and then the server binds properties to the socket by using port, address, etc., which are information required for communication.

Server creates a listen socket to receive the client's connection, and client's connection is performed through listen socket. Here, the server accepts connection from the client, and takes the first connection from the queue where connections that have not been accepted and processed are waiting, to create a new connected socket. The client calls 'Connect' and attempts to connect to server, and, when the server calls 'Accept', the server creates a connection socket by which it communicates with the client.

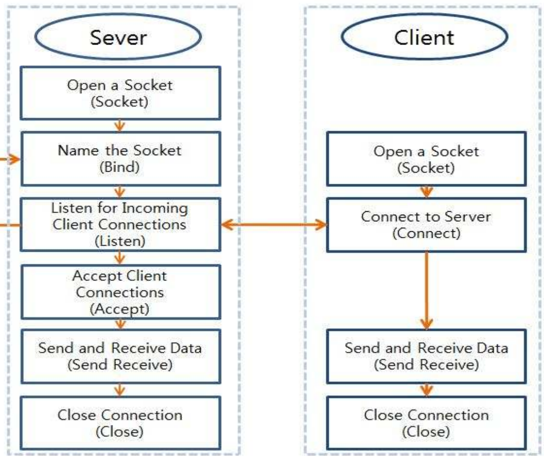

Fig. 5. Block of server and client

D. Emergency Patient Notification

As shown in Figure 6, the overall system operates the webcam and sensor through serial communication between embedded board and sensor control board with ATmega128. Embedded board and PC, through wireless network communication, enable transmission of webcam and sensor data.

Emergency situation is classified as normal section, caution section, and emergency section based on the normal pulse rate variability of the users existing in the DB as shown in Figure 6.

When the pulse wave of a user enters the caution section, the manager checks the primary situation based on the image data received by camera, and determines emergency. If the user's pulse wave stopped or excessively rose to the emergency section in 3 seconds, it is determined as an emergency situation. During emergency situation, call for rescue is made without waiting for the primary response from the management system.

As an exception, the design enabled the user to directly manipulate the touch sensor attached to the hardware and notify the management system of abnormality, even if the pulse wave remains in the normal section.

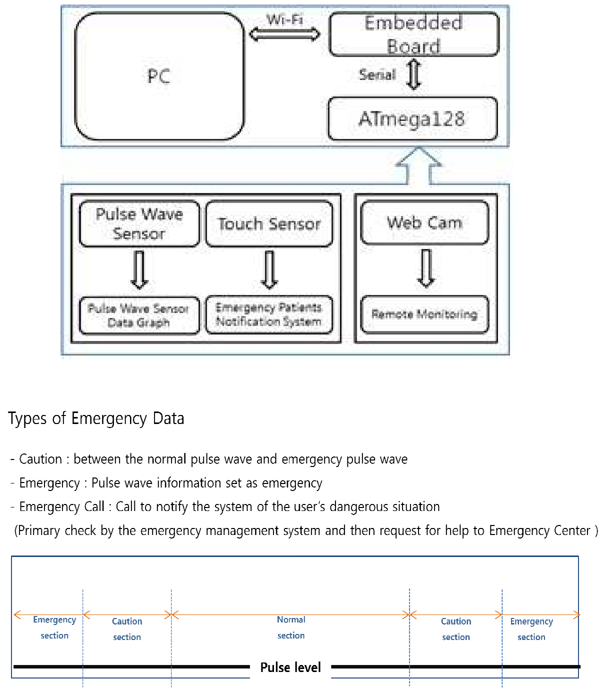

Fig. 6. Block diagram of the overall system (upper) and emergency determination based on pulse wave level (lower)

4. EXPERIMENTAL RESULT

In experiment, a client hardware which consists of a pulse wave sensor, touch switch and embedded board is installed on a foldable chair for the proposed U-Healthcare system as shown in Figure 7.

Fig. 7. Emergency patient notification system

In the management server system, the visual scene captured from a remote camera, pulse wave graph, and pulse rate per minute sent from client are monitored in real-time. Finally, the notification is alarmed when the pulse wave of the patient enters either the caution or emergency section while a patient is seated as shown in Figure 8.

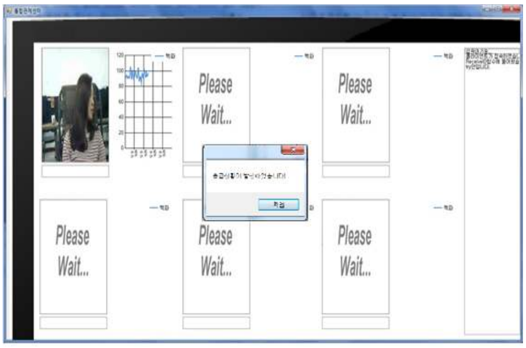

Fig. 8. Notification of the management system after detecting an abnormality

Emergency detection tests using remote pulse wave data was conducted to validate the reliability and the effectiveness of the proposed system. The result of emergency detection test is shown in Table 1. The test included a situation of excessive or low pulse rate and one where the pulse rate stops. The rate of recognition by situations was calculated as a percentage by checking the number of times when each situation was recognized in each test and dividing it by the number of test attempts.

Table 1. Result of emergency detection test

Situation	No. of tests	No. of successful recognition	Recognition rate (%)
Stopped pulse rate	50	50	100
Weak pulse rate	50	46	92
Excessive pulse rate	50	44	88
Total	150	140	93

In the simulation, except when there was contact failure with the pulse wave sensor, it showed 93% of recognition rate from 150 times of tests.

4. CONCLUSION

In this study, real-time image verification through Ip camera and emergency monitoring service using the pulse wave sensor button were built; requirements for building a U-Healthcare system were defined; and a direction for service to satisfy them were suggested.

This study was progressed by real-time image verification through webcam; putting on the pulse wave sensor; recognizing pulse rate information; translating the pulse wave data into a graph; sending pulse wave abnormality; monitoring pulse wave abnormality; and emergency response in the order. Emergency monitoring service operation server using pulse wave sensor manages the pulse wave information of the subject; monitors the pulse wave information in real-time; verifies the real-time image; and notifies the relevant emergency center of an emergency situation. The service built in this study is a general and expandable model that can be applied to most emergency medical services related to U-Healthcare, and can be used for a wide range of services from management of the elderly, severely disabled people, people with chronic diseases, people exposed to high-risk patients, children who live alone, and emergency medical service.

Through experiment, we performed emergency detection tests to check the status of a remote patient based on the pulse wave sensor data.

If more various bio-signal sensors such as blood pressure, cardiogram, and blood sugar are used, more accurate and detailed monitoring services can be provided for U-Healthcare. We expect that the use of U-Healthcare service will be incorporated with various fields including home security and wearable computer in addition to medical IT technology.

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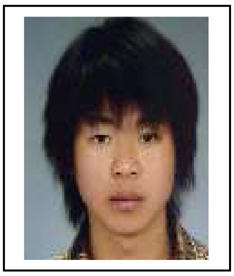

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