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Ubiquitous Healthcare System for Analysis of Chronic Patients' Biological and Lifelog Data

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ABSTRACT For the prevention and management of diseases in chronic patients, attention has been directed at ubiquitous healthcare systems in order to reduce medical expenses and provide high-quality medical services at different places, including hospitals and homes. In this paper, a ubiquitous healthcare system has been proposed in order to care for a chronic patient, to be used by a nurse or a care professional at the patient's residence. It comprises a portable bio-signal acquisition device, smartphone application, and ubiquitous health server. The smartphone application collects the patient information, including lifelog and the bio-signals from the device, and transfers the patient information through bio-signals to the ubiquitous health server. The ubiquitous health server monitors the bio-signals with the help of lifelog, analyzes the patient's health state, and alerts medical staff on symptoms of any illness. The proposed system collects five types of bio-signals from patients using the acquisition device, automatically monitors and analyzes their bio-data with lifelog, displays the state of their health as determined by the analysis, using graphical representation, such that the doctor can understand the patient's condition and undertake an appropriate medical treatment procedure.

INDEX TERMS Ubiquitous health, health state, bio-signal analysis, lifelog.

I. INTRODUCTION

Considerable attention has been given to ubiquitous healthcare systems for the prevention and management of diseases in chronic patients who require long-term care, in order to meet the paradigm shift in medical services with regard to diagnosis and treatment, involving a high level of medical care and aiding saving of medical expenses [1]. In addition, through ubiquitous health care systems, medical services can be retained and continuously utilised for improving a patient's physical condition at all times [2].

A ubiquitous healthcare system usually has three components: a portable device that receives the patient's bio-signals, an application in a smartphone or a special device that transmits the acquired bio-signals to a server with filtering, and a server that monitors and analyses the patient's bio-signals with lifelog data [3]. The bio-signal acquisition device should have mobility, for being carried when visiting patients. It should also have accuracy in terms of bio-signal acquisition. Since the volume of the acquired bio-signal data, including electrocardiogram (ECG), electromyogram (EMG) and general physical data, is huge, advanced technology and communication infrastructure will be required. The monitoring technology aims at reducing the risk in patients by automatically analysing their health status through the use of bio-signals with lifelog in advance. In this field, many studies are currently in progress [1], [3].

In this paper, a ubiquitous healthcare system has been designed and implemented for chronic patients, to be used by a nurse or care professional, in which a portable bio-signals acquisition device that uses five types of sensors to acquire biometric information including ECG, EMG, blood pressure, oxygen saturation, and body temperature, has been developed. Section 2 reviews the previous work pertaining to ubiquitous healthcare. Section 3 describes the design and implementation of the ubiquitous healthcare system and explains its flow. Section 4 explains bio-analysis, and Section 5 forms the conclusion.

II. RELATED WORK

With a growing population with chronic diseases including aged people, ubiquitous healthcare service is needed because people are looking for patient-centered health

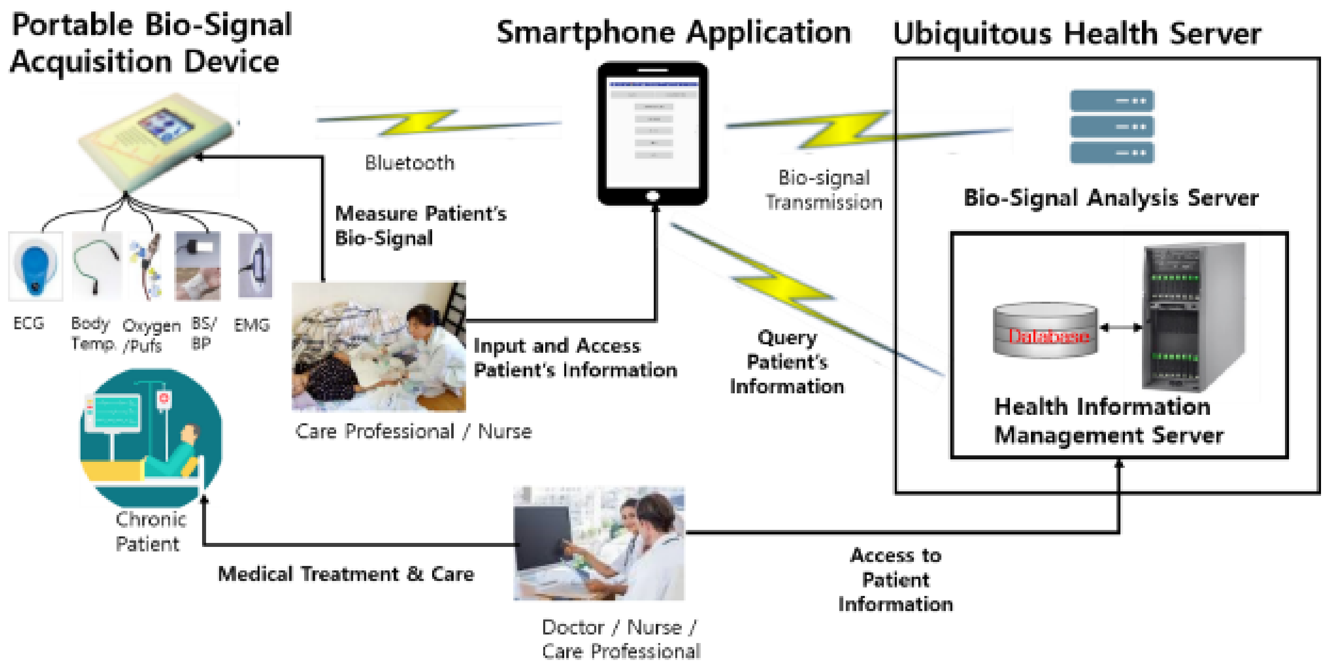


FIGURE 1. Structure of ubiquitous health system.

services, rather than the classical hospital-centered model [1]. Ubiquitous healthcare system provides an analysis of health state by instant attention to the diseases and gives patients an emergency alert, when any chronic problem occurs. [3] In addition, it also helps the service providers to have servers to save and handle patient information, remotely monitor the patient's biological data in real-time and provide feedback [4], [5].

Through ubiquitous computing technologies and environment, participants of the ubiquitous healthcare system including doctors, nurses and patients, combined with appliances and medicine, would be monitored and managed continuously [6].

In a typical ubiquitous healthcare system, sensors such as ECG, EMG and body temperature are embedded in the measuring device used for patients or directly attached to patients, and transmit their data via wireless interface to a health information management server. This data is then integrated into the hospital server, for use by the doctor in medical treatment [7]. Therefore, the system uses a large number of environmental sensors, patient sensors and actuators, for monitoring and improving patients' physical and mental conditions, including lifelog [8], [9].

In recent years, advances in hardware and software components including sensors, mobile devices and cloud services, have unleashed the potential for ubiquitous healthcare systems. For example, a wearable sensor system that measures a patient's state by monitoring movement, physiology and environment, was released for applications for Parkinson's disease, stroke, and head and neck injuries [10]. A healthcare system was incorporated for remote monitoring by medical personnel, to keep track of significant physiological signs and combining them with other contextual information, with low-cost, user-friendly sensing and actuating systems [11].

Since the proposed system will be used by nurses or care professionals at the patients' residence instead of by patients themselves at the hospital, specific ubiquitous healthcare systems with greater self-monitoring and care by all individuals need to be investigated. For example, HealthPal is an intelligent dialogue-based mobile health-monitoring system for the elderly, offering information about their health condition on a daily basis, in their preferred environment [12], [13]. Healthpal users need not rely on the assistance of caretakers, if they so wish. But another research reveals that previous experience of care professionals needs to be considered as a strategy for ubiquitous healthcare. Patient information is collected by care professions for taking good care of their patients, and the system provides early diagnosis for checking the state of health [14], [15].

In our previous work, a ubiquitous healthcare system for use by care professionals has been designed and implemented, comprised of three main components: a compact bio-signal acquisition terminal, smart phone application that transfers multiplex bio-signals to the health management server, and health management server that monitors the bio-signals and analyses a patient's health state [16].

III. DESIGN AND IMPLEMENTATION OF THE UBIQUITOUS HEALTHCARE SYSTEM

The ubiquitous healthcare system has been proposed in order to care for chronic patients, to be used by a nurse or a care professional at the patients' residence. It consists of a portable bio-signal acquisition device, a smartphone application, and a ubiquitous health server, as shown in Fig. 1. One can measure five types of bio-signals from the patients at their residence through the use of the acquisition device, as the patients might not mesaure their bio-signal by themselves. From the smartphone application, patient information is retrieved by a nurse or care professional, and the patient's related health profile and bio-signals are transferred to the ubiquitous health server, which in turn is composed of two servers that have their own functions: bio-signal analysis and health information management. The bio-signal analysis server monitors bio-signals with the lifelog maintained by the health information management server, analyses the patient's health state, and alerts medical staff on symptoms of any illness. The health information management server automatically stores analysed bio-data along with basic patient information and lifelog in the database, displays the state of the patient's health from the analysis, using graphical representation, such that the doctor can understand and prescribe the appropriate medical treatment or care, which will also be saved in the database, forming the patient's profile and lifelog.

Unlike our previous work, designed for use by a care professional [16], the proposed system would be used by a nurse who can give orders to the care professional for getting the patient's bio information including lifelog data, gathers information, and effects medical treatment as ordered by the doctor. Especially functionality of the smartphone application from new procedures, and health state analysis by enhanced algorithms including simple clustering algorithm in the system is greatly improved.

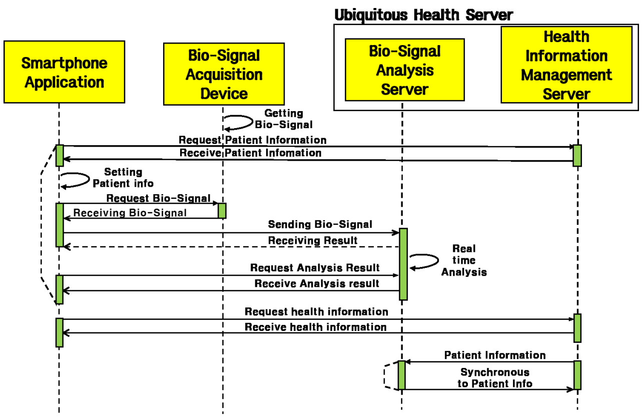


FIGURE 2. The system operation scenario.

The system operation scenario is depicted in Fig. 2. Since smartphone is a tool used by a care professional or a nurse, the operation begins with the smartphone application. The smartphone application requests patient's information, including lifelog, and receives it, and it acquires bio-signal from the bio-signal acquisition device. The smartphone application sends bio-signal with input data regarding the patient, including the identification number of the care professional or the nurse, type of bio-signal, measuring time, specific comments pertaining to the patient, and so on, to the ubiquitous health server. The ubiquitous health server returns analysed big-signal results and health information as the smartphone application requests.

A. PORTABLE BIO-SIGNAL ACQUISITION DEVICE

The portable bio-signal acquisition device is a small device that measures the ECG, EMG, body temperature, blood pressure, and oxygen saturation in order to obtain pertinent signals, to be used by a nurse or a care professional. The developed portable bio-signal terminal acquisition device is shown in Fig. 3.

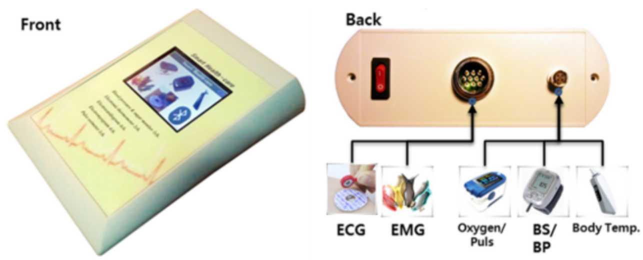


FIGURE 3. The developed portable bio-signal acquisition device.

The device immediately acquires the patient's bio-signals and plays the role using the five sensors. Fig. 4 presents a block diagram of the portable device. In the device, the biometric information that is transmitted to the smartphone via Bluetooth is sent to the bio-signal analysis server, which is a part of the ubiquitous health server; and the analysed data is stored in the database in an encrypted form. Storing the analysed data in the ubiquitous health server database makes it easier for a care professional to use a smartphone in managing the data, monitoring patients' illness, and offering better healthcare service.

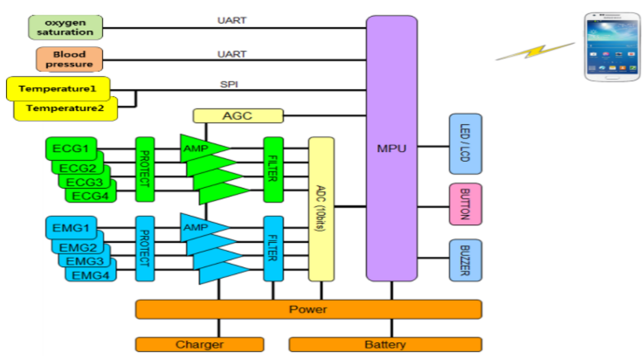


FIGURE 4. Block diagram of the portable terminal.

B. SMARTPHONE APPLICATION

The smartphone application obtains inputs regarding the patient from a care professional or a nurse, measures bio-signals and transmits the acquired bio-signals to the ubiquitous health server. The patient can process the inputs with respect to the smartphone application, as shown in Fig. 5. Since the user of the smartphone application is a nurse or a care professional, the application offers appropriate functions

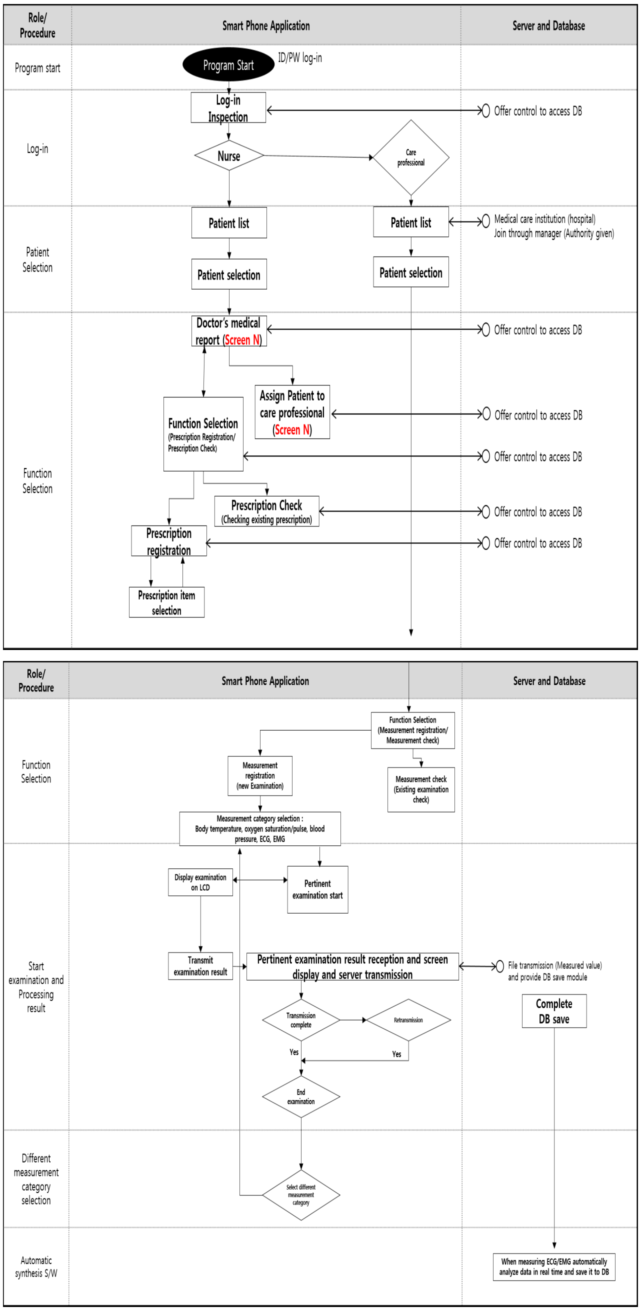


FIGURE 5. Flow chart of patient care process in the smartphone application.

in accordance with the role of each user. Each user can check the patient list and select a particular patient who requires care. The nurse checks the doctor's medical report and performs necessary nursing treatment based on that. If the nurse needs the support of the care professional, he/she may assign the patient to one.

Measurement of the bio-signal is carried out by a nurse or a care professional who makes the scheduled home visit. They check the medical history and provide care. The measurement category selection screen of the smartphone application is shown in Fig 6.

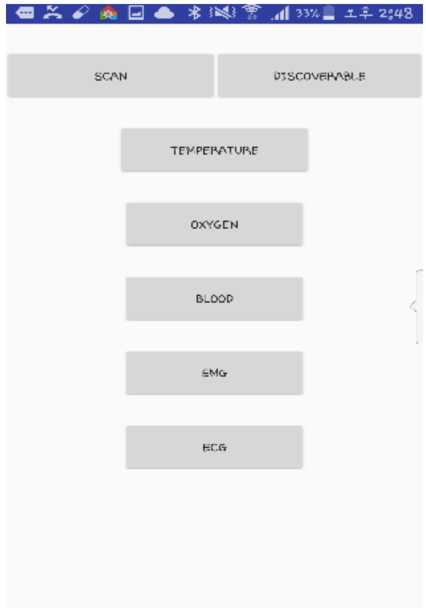


FIGURE 6. Measurement category selection screen of a smart phone application.

C. UBIQUITOUS HEALTH SERVER

The ubiquitous health server is comprised of the bio-signal analysis server and the health information management server. The bio-signal analysis server collects the bio-signals acquired from the patient and saves them in the biometric data system for processing.

The health information management server keeps data in a database that the user can access. Data is encrypted using hash functions for reasons of data security. The server page is divided by the agent into hospitals and nursing homes.

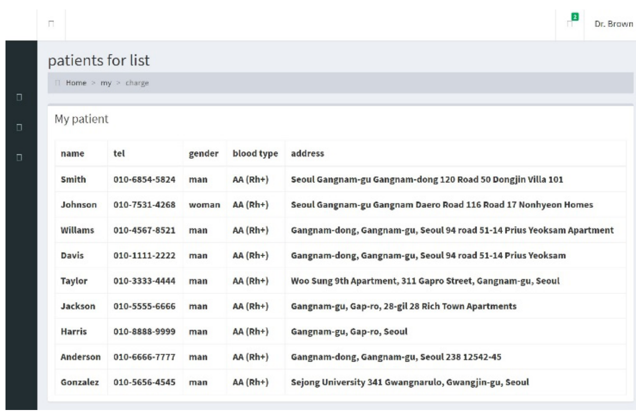


FIGURE 7. Main page of health information management server.

As shown in Fig. 7, the homepage of the health information management server, and the entire page layout are the same for each agent. It displays the information of the patient in charge and their medical history. The nursing home has a page that registers the schedule for visiting patients who are receiving home care.

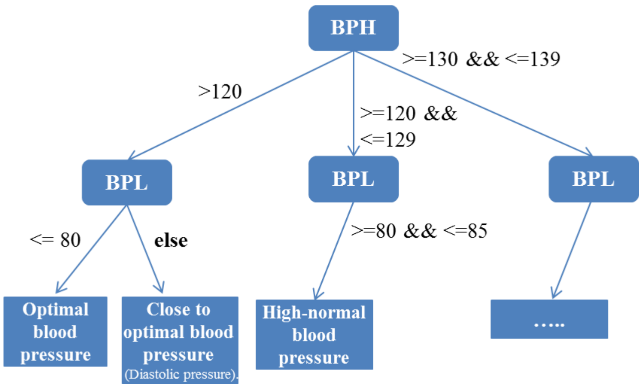


FIGURE 8. Decision tree for analysis of numeric data (blood pressure).

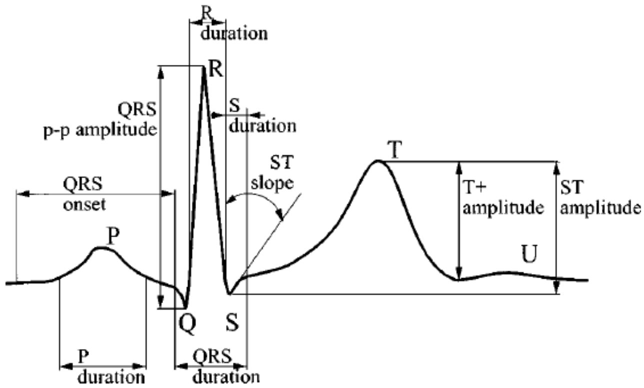
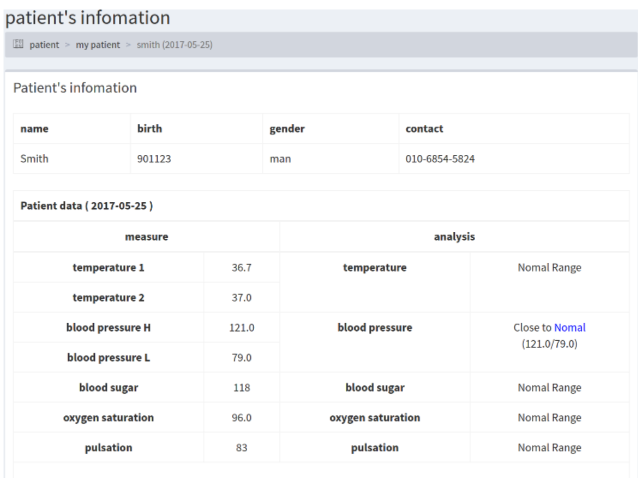


FIGURE 10. Features used for waveform classification of ECG.

IV. BIOMETRIC INFORMATION FOR BIO-SIGNAL ANALYSIS

Biometric information is acquired by analysing bio-signal data, composed of numerical data and time-series data. Example of numerical data are body temperature and oxygen saturation, represented as specific numbers. Time-series is represented as multiple values over a period of time, and examples are the value of ECG and EMG signals. In the analysis of numerical data such as blood pressure, we used a decision tree classifier as show in Fig 8.

A result obtained from the analysis of numerical data including blood pressure, body temperature, blood sugar, oxygen saturation and pulsation, is shown in Fig. 9.


patient's infomation

patient > my patient > smith (2017-05-25)

Patient's infomation

name	birth	gender	contact
Smith	901123	man	010-6854-5824

Patient data (2017-05-25)

measure		analysis	
temperature 1	36.7	temperature	Nomal Range
temperature 2	37.0		
blood pressure H	121.0	blood pressure	Close to Nomal (121.0/79.0)
blood pressure L	79.0		
blood sugar	118	blood sugar	Nomal Range
oxygen saturation	96.0	oxygen saturation	Nomal Range
pulsation	83	pulsation	Nomal Range

FIGURE 9. Result of numerical data analysis.

For time-series data for ECG, specific analysis using R-waveform is performed for evaluating a patient's health status. The ECG offers Q, R, and S waveforms, which have relatively distinct signal separations, as shown in Fig. 10.

The ECG data from the portable bio-signal acquisition device are stored in the database in 200 real number values per second. The analysis process identifies the positions of the R-waveform, R-R interval, and QRS interval's characteristics from the stored EEG values and the identified information are saved in the database for detecting disease.

For identification of the R-waveform, we need to detect the peak value of R-waveform, which is called R-peak in this paper. We used the stored ECG data every 3 seconds for the detection of R-peak values. For a person in a normal state of health, R-peak is detected for every 0.75 seconds. However, for a person with a high heartbeat, R-peak is detected even twice in the same duration. For detecting R-peak values, we filtered specific ECG values with patterns of ascending slopes and descending slopes at that value, that is shaped as "^," clustered them by their standard deviation. By choosing the cluster with highest average, we can achieves R-peak values, as shown in Fig 11.

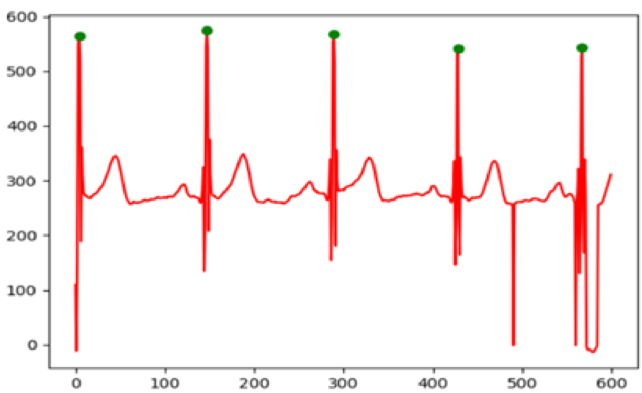
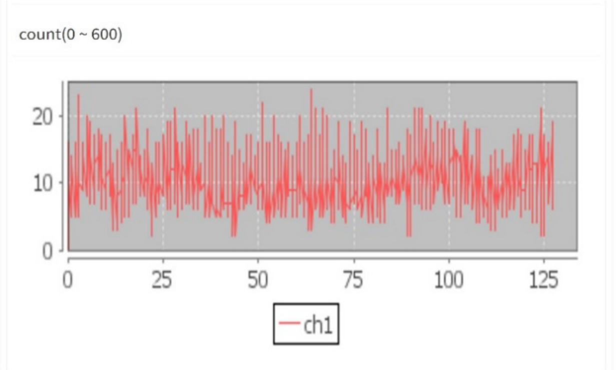


FIGURE 11. R-peak values marked in green after clustering.

We can easily get R-waveform and R-R intervals from the achieved R-peak values. If the variation of R-R interval value is large, we know that the ECG rate is irregular. To get Q, R and S waveforms, we selected specific stored ECG values with patterns of descending slopes and ascending slopes at that value, shaped as "v" and by filtering, clustered them by their standard deviation. By choosing the clusters with the lowest average and the second lowest average, we can achieve Q and S waveforms, depending on the location, i.e., the left side of the R-peak or right side.

The R-R interval and QRS interval serve as important indicators of various heart diseases, such as arrhythmia. A result from an ECG analysis is shown in Fig. 12.



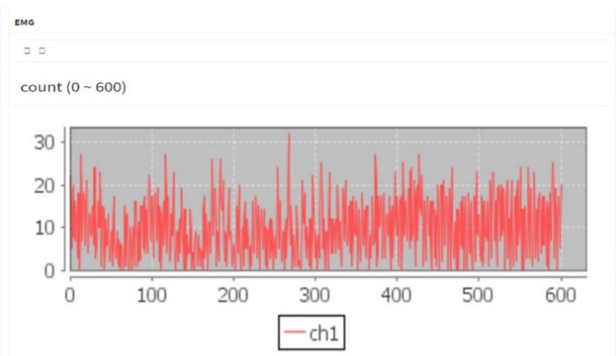
	Average of detection	Normal index
Heart rate	21.0	60 ~ 100 /m
ECG Rhythm	irregular	regular/irregular
RR Rhythm	3.329	0.6 ~ 1.0 Sec
QRS-Interval	-0.027	0.06 ~ 0.10 Sec
Measurement signal reliability	100%	

FIGURE 12. **Results of ECG analysis.**

The EMG signals obtained from the portable bio-signal acquisition device are formed into block units for every 0.5 seconds, and the average of the EMG values in the block is calculated and used as the baseline for blocks. The EMG signals are classified as normal, error, and risk, by the following formula (1).

$$EMG_{class} = \left\{ \begin{array}{l} normal\ (x) = \{x|B-80 \le x \le B+80\} \\ error\ (x) = \left\{ \begin{array}{l} x|B-150 \le x \le B-80 \\ x|B+80 \le x \le B+150 \end{array} \right\} \\ risk\ (x) = \left\{ \begin{array}{l} x|B-150 \le x \\ x|B+150 \ge x \end{array} \right\} \\ \end{array} \right\} \quad (1)$$

where B stands for baseline



Normal spontaneous potential	92.938
Abnormal spontaneous dislocation	7.062
Measurement Signal Reliability	83.25%

FIGURE 13. **Results of EMG analysis.**

A result from the EMG analysis is shown in Fig. 13.

V. CONCLUSION

A ubiquitous healthcare system has been proposed for providing high-quality medical services for the prevention and management of diseases in chronic patients, to be used by a nurse or a care professional at the patient's residence. It is comprised of a portable bio-signal acquisition device, a smartphone application, and a ubiquitous health server. It monitors and analyses the patients' bio-data with the help of lifelog, displays the state of their health from the analysis, using graphical representation, such that the doctor can understand and prescribe an appropriate medical treatment or care order.

We focused especially on the functionality of the smartphone application from new procedures for caring and medical treatment of patients by a nurse. In order to overcome low bio-signal reliability in the portable bio-signal acquisition device, we designed simple clustering algorithms for detecting R-peaks and used it in the bio-signal analysis of Q, R, and S waveforms, extracting highly reliable features from the signals.

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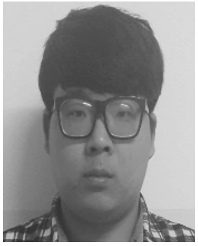

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