

Healthcare Services with Bio-Clothes under a Cloud Computing Environment

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Abstract. Clothing with biosensors, so-called bio-clothes, may in the future serve as wearable computing devices for health promotion and sports activity. It is self-evident that when bio-clothes work with appropriate software to support healthcare services, they eventually become valuable and acceptable to users. Employing bio-clothes, our team has developed a cloud computing environment to support personalized healthcare services on one hand, and three healthcare applications using and analyzing physiological signals of electrocardiographic (ECG) and respiration data obtained by bio-clothes on the other hand. In particular, these three software applications are in the development: (1) Calorie Tracker helping to manage obesity by physical exercise, (2) Stress Tracker enabling assessment of the user's autonomous nervous system (ANS), which controls mental stress, and (3) Biofeedback System making the user train themselves to keep ANS balance by controlling their respiration. Presenting three applications working under the given cloud environment, this paper sheds some light on potentiality of both bio-clothes and related healthcare services.

Keywords: bio-clothes; biosensor; cloud computing; digital yarn; healthcare; service; software; vital sign; wearable computing; wellness wear

1 Introduction

In the near future, clothing will not be merely worn. Instead, it can become a wearable computer, consisting of small, comfortable, and intelligent sensors and devices. Such smart clothes have great potential for healthcare in everyday life. When clothes with noninvasive biosensors, called 'wellness wear,' are in real use, vital signs such as electrocardiograph (ECG), respiration, blood pressure, SpO₂, and body temperature data can be obtained readily at anytime and anywhere. This will certainly increase opportunities for better healthcare, including obesity control, stress

management, and chronic disease prevention and care. Generally, wearable systems including wellness wear enable the continuous monitoring of health conditions and provide real-time feedback about one's long-term health status, and can even offer alarms for potentially health-threatening situations [1].

In particular, software solutions and services are a key element in the success of the whole wellness wear system. This paper introduces a cloud-based personalized healthcare system based on wellness wear. It consists of clothes with biosensors, a cloud computing environment, and healthcare applications. By building and adopting a cloud computing based web, healthcare services are provided in different OSs, and different devices such as smart phones, pads, PCs, etc.

Section 2 describes a wellness wear system and a cloud environment that we have developed as background. Section 3 presents three healthcare software applications working with wellness wear including ECG and respiration sensors and the cloud environment: a calorie-tracking service, a stress-tracking service, and a biofeedback service that we implemented, followed by our conclusion.

2 Background

2.1 A Wellness Wear System

The wellness wear system that we are currently developing is an integrated and complex system demanding the fusion of the technologies of fiber engineering, electronic engineering, software engineering, and medical informatics [2]. It consists of wellness wear, biosensors, hardware, and software. Advanced sensor technology is needed to secure the accuracy and reliability of the signals. Digital or conductive yarns play a key role in forming a BAN within the clothes [3]. Further, hardware techniques for digital signal processing (DSP), wired and wireless communication, and the integration of multiple biosensors are required. Finally, software is of great importance to provide medical services through wellness wear. Aspects of software include applications realizing services, data transmission, and a foundation framework on which the whole wellness wear system and the application programs are built.

2.1 Cloud Environment for Vital Signs-based Healthcare Systems

Cloud computing which takes advantage of the internet technology such as the Web 2.0 enables to realize delivery models of Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Together with virtual-server technology, SaaS becomes crucial to success in a cloud environment. The cloud computing environment that we propose reflects an SaaS model [4].

Figure 1 shows a summary of the proposed framework for vital signs-oriented healthcare system. The framework that we suggest has the characteristics. First, vital signals obtained are transmitted to the server using W3C standardized messaging. Second, information is extracted from the values related to features that are required to evaluate the health state from the vital signals raw data. Third, both the raw data

and the extracted feature data are represented as XML document, based on HL7, and saved in a personalized repository. Forth, it calculates and extracts the health state using OCL including an OCL evaluator. Fifth, the healthcare component enables users to access services with various devices using the standardized W3C message protocol.

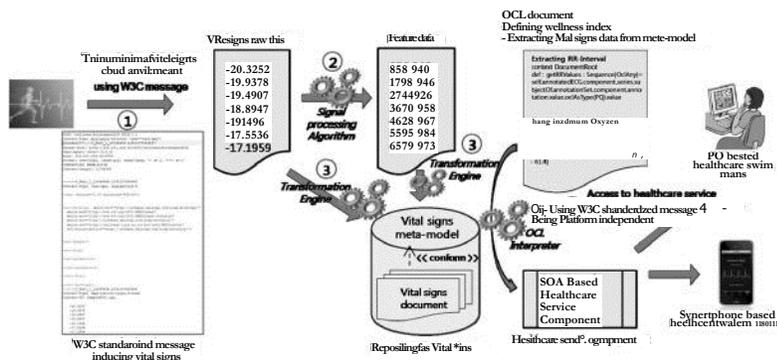


Fig. 1. Proposed software framework fitting the wellness wear context.

3 Healthcare Software Applications

Once a cloud computing environment is built to provide healthcare services utilizing physiological signals, software applications can be developed in connection with the wellness wear system. This section presents three examples of such applications that we have developed: (1) Calorie Tracker [2] helping to manage obesity by physical exercise, (2) Stress Tracker [4] enabling assessment of the user's autonomous nervous system (ANS), which controls mental stress, and (3) Biofeedback System making the user train themselves to keep ANS balance by controlling their respiration. The first two applications are Android-based smart phone apps using heart rate variability (HRV) extracted from ECG data, while the third application, Biofeedback System, employs both HRV and respiration data acquired from the bio-clothes. Here, a smart phone serves as a device that handles client programs, as well as a terminal exchanging data with a server. For example, the ECG data acquired from wellness wear are transferred to a smart phone using Bluetooth, and the system on the smart phone transmits data to the server, using XML conforming to the HL7 standard.

3.1 Calorie Tracker

Calorie Tracker is a software application to manage obesity. It obtains and stores ECGs from wellness wear when the wearer is performing an activity, such as walking or running, for a period of time (e.g., 5 min). After ECG data has been acquired over a period of time, the Calorie Tracker uses it to extract heart-rate variability (HRV). HRV is a time series of intervals between successive R peaks in the ECG.

Calorie Tracker calculates the number of calories burned and body mass index (**BMI**) using HRV and demographic data, such as the user's weight, height, age, and gender. It finally provides the user with a weight-loss program. For example, it may recommend, "You need light exercise for two hours a day to reduce your weight by 1 kg in a month." Based on the HRV data recorded during a certain period of the user's activity (e.g., 5 or 10 min), the system determines the intensity of exercise for the specific user. Then, it makes a recommendation for an appropriate exercise level to help the user reduce weight according to his or her weight-loss goals.

3.2 Stress Tracker

Stress Tracker runs on Android-based smart phones, and like the Calorie Tracker, analyzes HRV data. It also evaluates the user's ANS, which controls mental stress, and gives appropriate feedback. For this, the program uses the standard deviation of all normal to normal RR intervals (SDNN) and its ratio of the low frequency (LF) and the high frequency (HF) from HRV. Generally, HRV is useful for evaluating the functions of the ANS. In particular, overactive ANS is an indicator of a system under current stress, and a balanced ANS is important for effective stress coping.

Similar to the Calorie Tracker, the user wears smart clothes to obtain the ECG data, while sitting for a certain period of time. Then, the stress tracker acquires and stores ECG data from the wellness wear, and extracts HRV from the ECG data measured. It finally responds to the user concerning the status of his or her ANS, using SDNN derived from HRV data to provide the user with information about whether his/her ANS response to stimuli is good or bad, using SDNN and the ratio of LF(Low Frequency) and the HF(High Frequency).

3.3 Biofeedback System

The third application is a biofeedback system currently in the development. It runs on Android-based smart phones and pads, and is designed to help maintain stable ANS and manage mental stress by controlling the breath. The system provides the user with an ideal breathing pattern so that the user can adjust his or her respiration to the guided pattern.

Figure 2 shows an example of the user interface in the biofeedback system. The biofeedback system captures and measures each respiration, by the respiration sensor included in wellness clothes. Suppose that the user trains his or her ANS by controlling breath for 5 minutes. During the measurement, the system analyzes the rate of breathing, including inhalation and exhalation, and the depth of breathing. The system shows if the user's breath is slow, good or fast. Further, it gives the user proper feedback, e.g. providing a voice message, "Breathe slower". It also shows the user the average BPM (Beats Per Minute) and the average RPM(Respiration Per Minute). In summary, the system can help user learn how to take breath to handle stress and ANS through repetitive trainings. In addition, the training of the user through breathing can adjust mental stress.

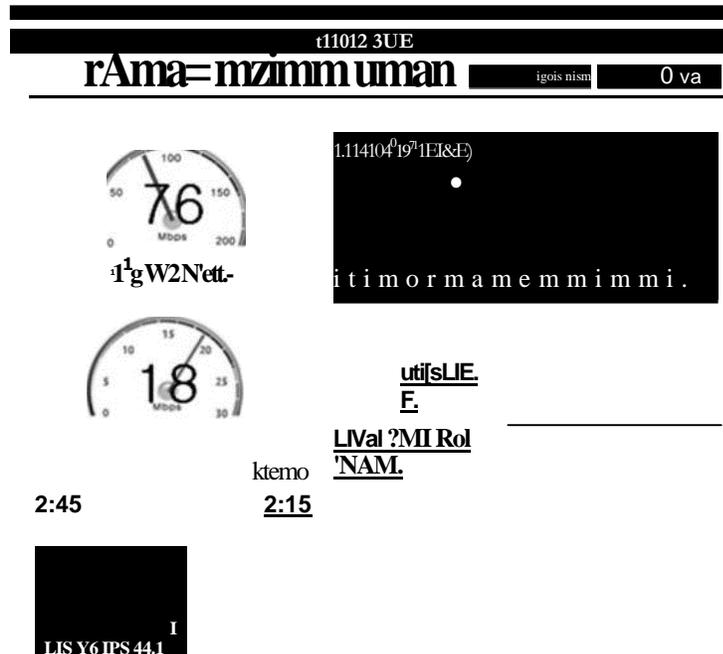


Fig. 2. An example of user interface (UI) of the biofeedback system

4 Conclusion

Bio-clothes, cloud computing, and software applications are three crucial components to realize ubiquitous healthcare. This paper briefly presented a wellness wear system consisting of these components, with a special emphasis on software applications, e. g. Calorie Tracker, Stress Tracker, and Biofeedback System that we developed. In the future, much more healthcare applications in use at anytime and at any place will be shown. Simultaneously, more comfortable and noninvasive bio-clothes will appear working with cloud computing environments. While research on healthcare services with bio-clothes is still in its infancy, we recognize its huge potential, and hope our discussion to help design and understand u-healthcare services with bio-clothes.

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