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Design of a Calorie Tracker Utilizing Heart Rate Variability Obtained by a Nanofiber Technique-based Wellness Wear System

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Smart clothes containing small, noninvasive biosensors to acquire bio-signals like electrocardiographs (ECG), known as nanofiber technique-based wellness wear, are promising wearable computing devices for better healthcare, including obesity control, stress management, and chronic disease prevention and care. With the introduction of such a wellness wear system, this paper presents a software application involving a calorie tracker. The calorie tracker, running on an Android-based smart phone, analyzes the ECG data obtained from wellness wear and provides a weight loss program using heart rate variability extracted from the ECG data.

Keywords: healthcare, heart rate variability, wearable computing, wellness wear.

1 Introduction

A new paradigm of ubiquitous healthcare has led to the emergence of new forms of medical practice in which healthcare can occur anytime and anywhere. In particular, wellness wear containing biosensors that continuously monitor electrocardiograph (ECG) data, respiration, SpO_2, blood pressure and other parameters, are expected to become important tools for healthcare in the future [1]. A wellness wear system constitutes an integrated system consisting of wellness wear, biosensors, hardware and software. While individual related systems have been proposed at a research level [e.g. 2-3], they are still in their infancy and many challenges remain. The two most crucial technologies are the sensors and software, since the value of the system highly hinges on the accuracy of the bio-signal data acquired by the sensors, the quality of the medical information extracted from that data by the software, and the medical content that is provided. Viewing the software structure and service content, as a key element for the success of the whole system, we present a software application involving a calorie tracker, running on an Android-based smart phone, which we have designed to be used with wellness wear.

2 A Wellness Wear System

2.1 Use Scenario

A primitive but fundamental scenario that we imagine is a user wearing smart clothes containing noninvasive and comfortable biosensors. While he or she is sitting, walking, running, or performing any other activity, vital signs acquired from the biosensors are recorded and transmitted to a terminal device (e.g., a smart phone) and/or a server. The software system analyzes the data and provides relevant healthcare recommendations. Figure 2.1 illustrates the flow of data in this scenario. In this section, we will mention only the most critical: bio-sensors, digital yarns, and the software framework.

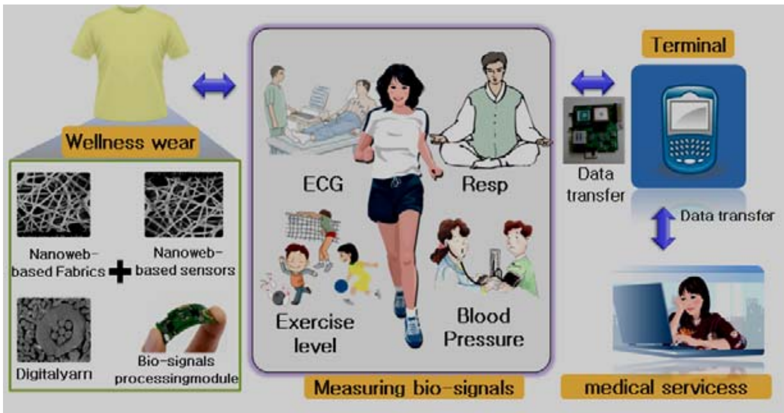

Figure 2.1: Overview of a Wellness Wear System

2.2 Biosensors

Biosensors are a crucial technology in the wellness wear system because everything hinges on how accurate and stable the bio-signals are that are obtained from the sensors. Moreover, since sensors are embedded in the smart clothes and touch the skin, they need to be small, comfortable, and noninvasive. This is one reason why nanofiber is required; nanofiber feels comfortable to wear even when sensors adhere to them.

2.3 Digital Yarns

Several techniques are involved in the production of wellness wear, including sewing, knitting, and embroidering technologies, but most important are the advanced and sophisticated techniques to produce digital yarns that are needed to transmit the bio-signal data. The conductive yarns within the clothes comprise a Body Area Network (BAN) for data transmission. An author of this paper, Dr. Gi-Soo Chung, has developed a digital yarn whose major material is a copper alloy [4]. The electrical resistance of it is relatively low, 7.5 Ω/m, and its transmission speed is very high, 80 Mbps.

2.4 Software Framework

Applications to provide medical service content are more complex and take longer to build than one might expect because of issues like standardization, interoperability, reusability, and reduction of maintenance cost. These factors require a sustainable and flexible software architecture before individual applications can be developed. To this end, we have developed a framework that underlies all application systems to come with wellness wear [5]. The primary idea is that vital signs obtained from smart clothes are transformed into a metamodel-based abstract tree, in which healthcare services are defined through Object Constraint Language (OCL) [6], with help from medical specialists and engineers. In particular, the framework expresses the bio-signal data as an HL7 metamodel [7]. Standardization, interoperability, and integration between the bio-signal data are thus easily and effectively realized.

3 Calorie Tracker

3.1 Background

Calorie trackers are useful in managing obesity. Obesity reduction is a top health priority today throughout most developed countries. Obesity not only affects one's physical appearance but also leads to a number of weight-related diseases, such as insulin resistance syndrome, cardiovascular disease, and type 2 diabetes. Three distinctive ways to reducing weight are bariatric surgery, FDA-approved drugs, and conventional methods of diet, exercise, and counseling. The calorie tracker described concerns the third method.

3.2 Functions

Following is a description of four key functions in the calorie tracker. First, it obtains and stores ECGs from wellness wear, as well as other general data such as the user's weight, height, age, and gender. In this case, the user inputs these general data into the calorie tracker. The user also has to give the system information as to whether he/she is at rest or active, is taking medications, or is diabetic. The user also wears smart bio-clothes to obtain ECG data, while performing an activity for a certain period of time, say 5 min. **Second**, the calorie tracker extracts heart-rate variability (HRV) from the ECG, measured over a certain period of time. HRV is a physiological phenomenon in which the interval between heart beats varies.

Figure 3.1: An Example of the User Interface in the Calorie Tracker

As a cycle length variability, HRV is a time series of intervals between successive R peaks in the ECG.

Note that ECGs consist of P-Q-R-S-T waves, with R peaks being the highest of the five. In general, HRV is useful for evaluating functions of the Autonomous Nervous System (ANS), whereas ECG is better for the diagnosis of various heart-related diseases. **Third**, the system calculates the number of calories burned and the Body Mass Index (BMI), using the HRVs and other general data. To be aware of energy expenditure—that is, how many calories are burned—is important in deciding how much and how intense exercise should be for each person. HRV is a very useful measure of energy expenditure, the calculation of which depends on age, weight, and gender, in addition to HRV. **Fourth**, it offers the user a weight loss program. For instance, it recommends, “You need light exercise for two hours a day to reduce weight by 1 kg in a month”. Based on the HRV data logged during a certain period of the user’s activity, say 5 min, the system determines the intensity of exercise for the user. Then, it makes a recommendation for an appropriate exercise level to help the user reduce weight. Figure 3.1 illustrates this case.

3.3 Technical Aspects

The calorie tracker is developed to run on Android-based smart phones. Here, a smart phone can be understood as a device that handles client programs, as well as a terminal exchanging data with a server. The ECG data acquired from wellness wear are transferred to a smart phone using Bluetooth, and the system on the smart phone transmits the data to the server, with the form of XML that conforms to the HL7 standard.

An important feature of the algorithm that calculates the user’s energy expenditure is its use of HRV data. To determine calorie consumption, the value of Maximal Oxygen Consumption per min ($\%VO_2max$) is obtained using HRV measurements, including the average resting HRV (HRV_R), and the maximal HRV (HRV_M). Here, HRV_M is assumed to equal “220 – age”. Eq. (3.1) shows how to get $\%VO_2max$ from these parameters [8].

$$\%VO_2\max = \frac{HRV - HRV_R + 10}{HRV_M - HRV_R} \qquad (3.1)$$

Next, the number of calories burned (CAL) during exercise for a given period (t) in min is calculated from $\%VO_2max$ and the user’s weight (M) in kg, by the gender [8]

$$\text{Male}: CAL = \frac{(3.83 \times t + 13) \times M \times \%VO_2 \max \times t}{0.2} \qquad (3.2)$$

$$\text{Female: CAL} = \frac{{(3.83 \times t + 13)}/{8} \times M \times \%VO_2\max \times t}{0.2} \qquad (3.3)$$

4 Conclusion

Until now, health management systems utilizing vital signs have been developed mainly for use at clinical institutions. With the rapid development of technology, however, new types of advanced systems enable medical care and promotion of health at home. Wellness wear containing biosensors, are an example of this new context. When they are available, bio-signals become crucial data for healthcare in our everyday lives. In this context, we believe that the calorie tracker, connected with wellness wear, has great value in the future for enabling healthcare including weight loss.

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