Development of sports health care system suitable to the fitness club environment

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Abstract— **This paper presents a sports health care system suitable to the fitness club environment. As improvement of quality of life, increasing interest of exercise, it has been studied and developed products briskly for exercise management. As such products are developed mainly for outdoors activity, however, it has a limitation to systematically manage exercise in consideration of fitness club environment. We want to overcome this limitation through by development of systematically exercise management system using interacting interface network. We devised system suitable to control and monitor systematic exercise using bio-module available for real-time bio-signal processing based on a novel algorithm that could reduce operation complexity when users do exercise in the fitness club environment. The overall system is composed of bio-module that can collect bio-signal information and analyze signal in real time, exercise equipment control module and exercise management server. Based on bio-signal information processed in real time, it is possible for exercise management prescription in real time according to user's health condition using organically interacting communication. We expect that our suggested system contribute to propagation and development of sports health care field.**

Keywords- sports health care, exercise management, fitness club, bio-signal processing in real time, interacting interface

I. INTRODUCTION

Since the rate of adult disease in the global population increase and necessity of exercise is on the rise, the systematic exercise management is much needed and system available for health care in the sports is recently studied briefly for products. Many people who want systematic exercise management wish to monitor their exercise quantity for exercise management when they do exercise in the fitness club or field using these products. As such products are developed mainly for outdoors sports activity, however, they are unsuitable to systematic exercise management and exercise monitoring when they are used in the fitness club environment. Due to absence of interaction with exercise equipment, it is impossible to systematically manage exercise in consideration of present state of exercise and health of users. Although the methods to control exercise equipments through by bio-signal information or position information was introduced [1], they focus on safe equipment control rather than exercise management. Most of the existing systems basically monitor heart rate to provide users with exercise information. Although some products provide exercise information by measuring bio-signal information (raw ECG, skin temperature, activity, etc), they are mostly developed for scientific sports research instead of general users. As most of products do not have function to process the own bio-signal analysis, they cannot manage and monitor exercise accurately and precisely by themselves. Thus, we devised system suitable to control and monitor systematic exercise based on module available for real-time bio-signal processing when users do exercise in the fitness club environment. The system should meet the following requirements for systematic exercise management in the fitness club environment.

- Wearable sensor that can efficiently acquire bio-signal information without restriction
- Bio-signal processing technology that can analyze signal in real time during exercise under heavy load
- Close interface between exercise equipment control modules and exercise management server
- Miniaturization and low power consumption

Based on the above conditions, we developed sports health care system based on the bio-feedback function through exercise monitoring and bio-signal information monitoring (detecting bio-signal information, analyzing ECG rhythm) in the fitness club.

II. SYSTEM CONFIGURATION

The overall system was composed of bio-module that could collect bio-signal information and analyze signal in real time, exercise equipment control module and exercise management server. Figure 1 shows a configuration diagram of overall system.

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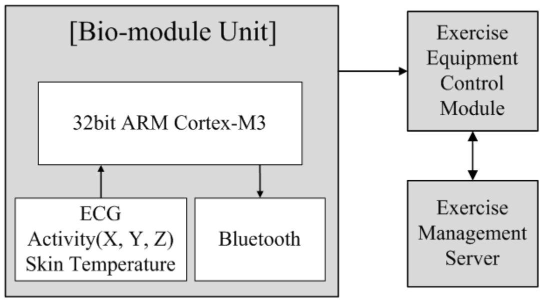

Figure 1. System configuration diagram.

A. Hardware

Bio-module hardware was composed of bio-signal measuring part, signal processing part, communication part and system control part.

1) Bio-signal measuring part: Bio-signal measuring part was designed to check the body conditions by using 1 channel ECG and activity chart of X, Y, Z axis using accelerometer and skin temperature using non-contacting infrared rays. While most of existing products only consider heart rate, we acquired ECG morphology. By this information, we could detect R-R interval and irregular pulses from raw ECG signal. When doing exercise in the fitness club, these parameters were used to set up the exercise level for monitoring users' exercise state and systematic exercise management. Activities were utilized for NLMS (normalized root mean square) algorithm that eliminates the motion artefact noise which may be generated during exercise and are used to calculate heart rate and exercise quantity. Measuring the skin temperature on the body surface could be utilized to assess the autonomic nervous system. Further, it could be utilized to check the users' activity state through the relative temperature change. The electrode was developed on the basis of wearable sensor (textile electrode: A-JIN ELECTRON co., Ltd., Republic of Korea) which is not limited to sports activity. It was made of washable materials that does not cause dermal problem. A full specification of conductive textile can be found in Table 1.

2) Signal processing part: Using 32bit ARM processer (ARM cortex-M3), the signal processor could process ECG signal in real time and algorithm was improved for high efficiency so that all signal could be processed in the bio-module. Furthermore, bio-module was more efficient in low power consumption as bio-signal process function and other functions for bio-module's operation could be performed simultaneously in real time using multi-tasking process by kernel.

3) Furthermore, these Bluetooth devices were used as the method to recognize users when the bio-module communicates with control module that control exercise equipment and transmit the exercise information to exercise management server.

4) System control part: System controller was composed of power controller, GPIO (general purpose input/output) controller and LCD panel controller that can check the performance information of devices at that time. These functions were automatically performed as each task is properly distributed by kernel in MCU (microcontroller unit).

TABLE I. CONDUCTIVE EXTILE ELECTRODE SPECIFICATION

Specification		
Item		***WPD-300-RG***
base material		polyester
width(mm)		1100 ± 5
density	warp	186 ± 10
	weft	116 ± 10
weight(g/㎡)		63.3 ± 5
thickness(mm)		0.05 ± 0.005
breaking strength(N)	warp	399.2 ±10
	weft	313.1 ± 10
elongation (%)	warp	30 ± 5
	weft	40 ± 5
surface resistance (Ω/sq)	min	0.008
	max	0.1
	avg.	less than 0.03
shielding effectiveness (dB)	100MHz	70
	1GHz	75
	15GHz	95

B. Firmware

Operating on the basis of multi-tasking process that uses 32bit MCU, firmware is composed of power management, signal acquisition, signal analysis, LCD display, GPIO scan and Bluetooth tasks. Distinct from the existing devices, the bio-signal process function realizes own exercise state monitoring and exercise management that uses bio-signal information.

Bio-signal process function processes the signal of ECG that was measured as the sampling of 500Hz. It was composed of algorithm that removes the noise that can occur during exercise, algorithm to detect the characteristic point of ECG signal and algorithm analysing ECG rhythm. The noise that can occur during exercise mainly divided into motion artefact noise and interference noise. The motion artefact noise could be removed by using NLMS algorithm using the activity signals measured with ECG concurrently. The high frequency interference noise could be removed by mathematical morphology algorithm which is useful to remove high frequency. It was processed in the stage before detecting algorithm. Algorithm detecting characteristic point of ECG operates on the basis of wavelet transform. General wavelet method is largely divided into CWT (continuous wavelet transform) and DWT (discrete wavelet transform), DWT is known to be more efficient to analyze bio-signal [2]. As DWT mode needs filter calculation for decomposition and reconstruction, however, it is subject to limit when processing signal in real time on the basis of devices [3]. Thus, we used the DWT mode based on impulse response to improve the calculation complexity of DWT. Since impulse response method realizes the fast convolution through FFT (fast fourier transform), signal can be efficiently processed in real time. We can acquire heart rate and R-R interval information through this algorithm. Figure 2 shows a signal processing based on real time. Algorithm analyzing ECG rhythm can acquire R-R interval calculated in the previous stage, bradycardia, tachycardia, irregular pulse, tachycardiac irregular pulse and bradycardiac irregular pulse. Further, it could detect PVC (premature ventricular contraction) by using DWT based on impulse response. Since DWT based on impulse response has value approximate to zero in the area where PVC occurs, it could be discerned from other signal. Figure 3 shows a detection of PVC signals.

C. *Interface to control exercise equipment*

It is important to control exercise equipment through interface between bio-module and exercise equipment control module for sports health care in the fitness club environment [4], [5]. The users were recognized by Bluetooth device embedded in the bio-module and the present exercise information and bio-signal analysis value were transmitted and stored to exercise management server through recognized identifier. The exercise equipment control module judged whether to apply bio-feedback on the basis of bio-signal information transmitted from the bio-module, then, if necessary for changing exercise prescription, new exercise prescription was acquired by requesting to exercise management server. Having exercise prescription on the exercise management server, it regulated the relevant present exercise level by monitoring the present health state of users. A Whole exercise program is controlled by Target heart rate (HR) range. If user's HR is out of range, exercise management server judged whether to change. Figure 4 shows a case that given exercise program was adequate to user. Figure 5 shows another one that given exercise prescription was inadequate to user; you can find that exercise information (speed, km/h) is changed during exercise.

D. *Information on the exercise prescription*

In the case of aerobic exercise, the exercise prescription was provided in accordance with the users' aerobic exercise capability (VO2max) acquired on the basis of IPAQ (international physical activity questionnaire). Each exercise levels in each stage were determined by the aerobic exercise capability. In the case of anaerobic exercise, the maximum exercise capability of relevant muscle was assessed before exercise to provide users with proper weight, times and set number so that they could appropriately improve exercise capability of relevant muscle. Then, users were guided to exercise in accordance with prescription.

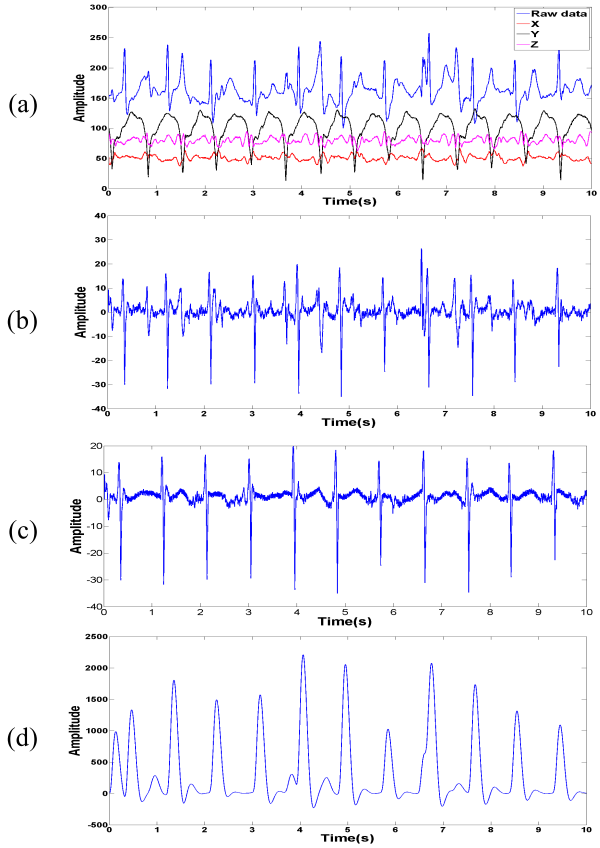

Figure 2. Signal processing for QRS complex detection; (a) raw ECG and activity signals, (b) signal removed motion artefact using activity information, (c) signal removed external interferences of high frequency, (d) QRS complex detectioncaption.

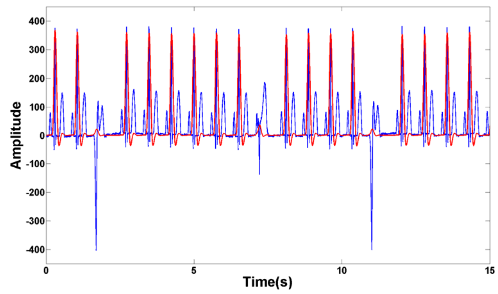

Figure 3. Signal processing for detection of PVC signals.

III. DISCUSSION

The sports health care system presented in this study was optimized for fitness club environment. As mentioned earlier, the system developed in this study satisfies all system requirements for systematic exercise management in the fitness club environment. The bio-signal information was acquired on the basis of wearable sensor that can be efficiently collected without restriction. In accordance with the users' exercise conditions; bio-signal processing technology was loaded on the basis of module that could analyse bio-signal in real time. Especially, more stable bio-signal information could be acquired through an algorithm that efficiently removes external interference noise and motion artefact noise occurring in heavy exercise to enhance aerobic exercise. The systematic and efficient exercise management could be provided through close interacting interface between exercise management server that has prescription information for exercise management and control module that controls exercise equipments. All functions of bio-module were designed to have the highest efficiency compared to power consumption when processing bio-signal and operating bio-module by using 32bit ARM processor. It is designed in the smallest size so that users can conveniently use them during exercise.

On the contrary, the existing products are unsuitable to be used in fitness club as they mainly focus on outdoors sports activity. The bio-signal information acquired in activity only judged the present state of users to regulate or induce the level or reminds the users of the present state by simple alarm. The feedback on the exercise information was usually checked by web server or separately developed system after exercise mainly in the single direction interface environment that can regulate exercise. The system developed in this study, therefore, supplements such demerit through close interacting interface. As well as interface improvement, we designed that it could provide users with more efficient and stable exercise control through bio-signal analysing technology that could judge whether heart functions are normal or not by analysing ECG rhythm and the users' present exercise state by checking bio-signal condition in real time.

Furthermore, the developed bio-module could be also used for outdoors activity as well as the existing products. As the communication device in the bio-module is Bluetooth, they can freely acquire bio-signal information only if devices and simple application capable of Bluetooth receipt were available. Moreover, they have the effect of exercise control like the existing products. Although the existing products and use time can be limited due to power consumption of Bluetooth communication, it can be fully used in consideration of the average personal daily hours of using fitness club. As the battery life is increased by 1.5 times by lowering the Bluetooth receipt sensitivity, the system is designed to be used for fitness club and outdoors activity for a day.

IV. CONCLUSIONS

We developed system that can provide users with better exercise management prescription for fitness club environment. We designed the system that provides users with more systematic and efficient exercise management based on designing on the basis of circuit design for miniaturization and low power consumption and robust algorithm for removing diverse noise factors that can occur in the fitness club environment and detecting bio-signal information parameters. Fully utilizable for outdoors activity, it is expected to contribute to propagation and development of sports health care system by developing outdoors communication terminal or smart phone application.

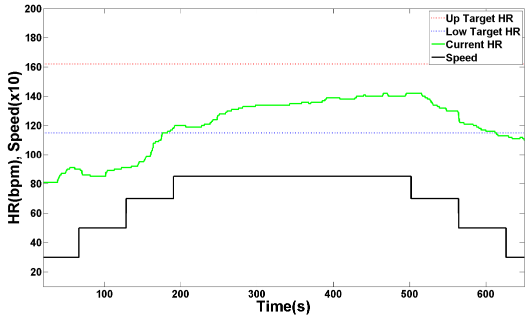

Figure 4. Exercise program that adequate to user.

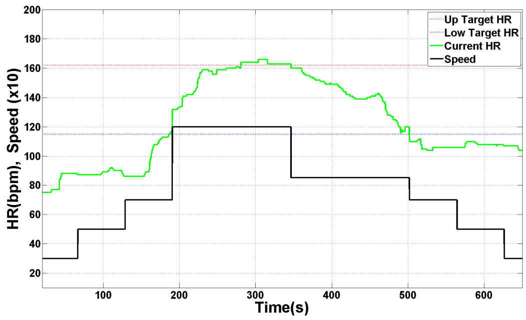

Figure 5. Exercise program that innadequate to user. Exercise information was changed because user's HR was out of target HR range.

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