Dynamic Measurement to Keep Suitable Physical Strength in Exercise by Body Area Network Sensing System

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Abstract. *This paper shows the dynamic measurement system to keep a constant physical strength by monitoring a heart rate in exercise. To monitor the heart rate, the measurement system had been constructed as a wearable and small scale wireless network system put on body. That was named Body area network sensing system(BANSS). BANSS is constructed with a host system and plural sensing nodes. Sensing node has sensors, microprocessor and near field communication device(NFCD). The sensing node is the subsystem which measures the physical parameters of user in exercise, and sends them to the host system regularly. BANSS is not only the system to measure physical parameters. By analysis of them, BANSS estimates present physical condition and generate a suitable advice to keep constant physical strength and informs it to the subject in exercise. In actual exercise by using BANSS, it is confirmed that constant physical strength is kept. This means that the interaction between user and BANSS has functioned successively.*

Keywords: sensing system, physical strength, dynamic measurement

1. Introduction

In daily life, quality of life (QOL) is the highest concern for all of people. They hope to keep it well and enhance it. Parameters of QOL are many kinds and different to each person. The parameters are concerning to the situations of living, health, family, friends, job, money, meal, hobby, social activity and so on. Especially, physical condition like health is the most basic and indispensable parameter. The physical condition depends on physical activity in daily life and changes dynamically. Then, to know the state of physical condition in detail, it is necessary to measure it continuously in daily life. Wearable and wireless body area network sensing system(BANSS) is the most suitable system to measure the dynamical physical condition continuously. Concerning to the measurement system like BANSS, there are several kinds of system [1-5]. In general, BANSS collects physical parameters on several measuring points on body, and send the data and information to host system. BANSS does not only measure physical parameters but also informs the state of physical conditions and give advices to control physical strength adequately to user. Additionally, BANSS will send the measurement data and the objective information of physical condition of user to family or home doctor.

2. Body Area Network Sensing System (BANSS)

To measure physical conditions in motion like walking, running and various kinds of physical activities in daily life, there are several parameters which are heart rate(HR), SPO2(Oxygen density in blood), body temperature, skin temperature, accelerations at measuring points of body (waist and foots [ankles]), impact transmitting in bones and so on. As measuring points of these parameters are distributed on body area, the sensing system forms near field wireless network to communicate measuring data and commands. Fig.1 shows a conceptual system construction.

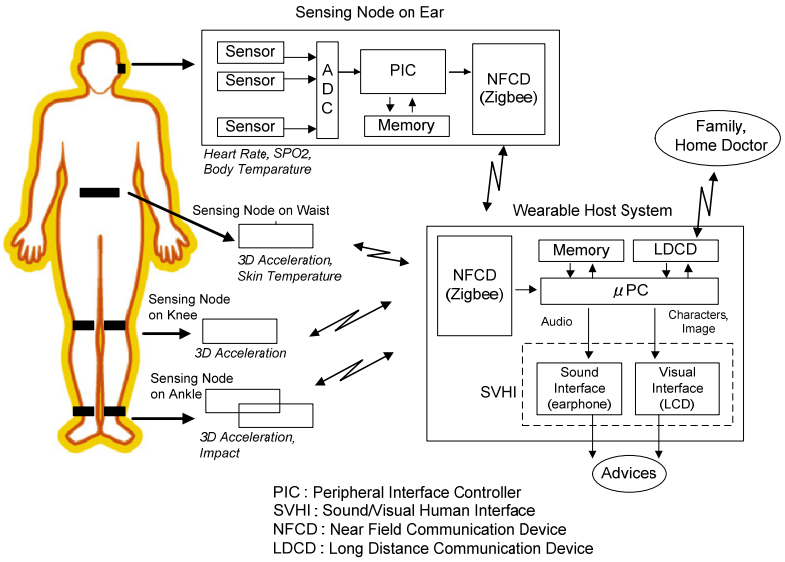

Fig.1. Concept of body area network sensing system (BANSS)

Sensing node is mainly constructed with some sensors, Analog-Digital Converter (8 channels, 10bits resolution, 0 - 3.3V input), Peripheral Interface Controller (PIC)(30MHz, 256kB memory, 32ch Digital I/O), some kinds of memory (total 1MB) and near field communication device (NFCD ; Zigbee) (communication distance 80cm, 8 channels). The kinds of sensors are different each sensing node llike heart rate, SPO2 and body temperature sensor on ear, acceleration and skin temperature sensors on waist, acceleration sensor on knees and acceleration and impact sensor on ankles. The main role of sensing node is the detection, analysis and transmission of physical condition parameters of user in exercise.

Host system is constructed with micro processor(SH3DSP), some kinds of memory, near field communication device (NFCD ; Zigbee), long distance communication device (LDCD) and sound/visual human interface (SVHI ; earphone, small size display[LCD]). The main role of host system is the objective estimation of physical conditions, the presentation of some advices to adjust physical conditions and the report of to family and home doctor. SVHI is the system for user to present current physical condition and advices for health condition. LDCD is the device to report the information of physical conditions of user to family and home doctor. The most suitable LDCD is handy phone using commercial telephone network.

3. Management of Suitable physical strength in Exercise by BANSS

Fig.2 shows the time transition of heart rate (blue line) in a motion sequence of quiet, walking, quiet, running and quiet(Lab. student ; male, age:23) which is measured by BANSS.

It has been confirmed that the heart rate responses according to human motions. In walking, the heart rate increased gradually. In the second quiet, the heart rate decreased gradually. In running, his heart rate increased quickly. He felt so tired at finish to run. This means that his physical condition became hard. In the third quiet, the heart rate decreased quickly.

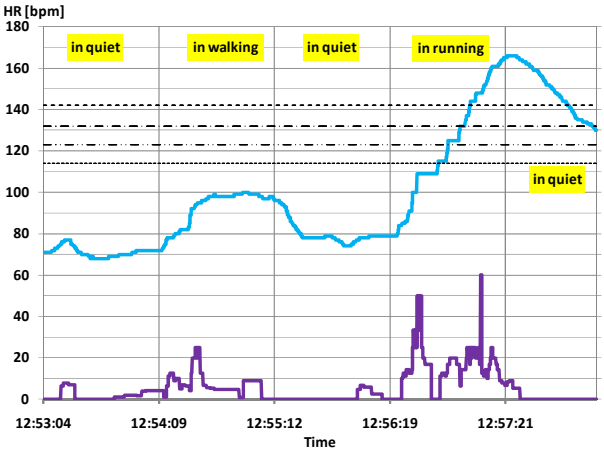

Fig.2. Time transition of heart rate in a motion sequence (blue line)

MET (Metabolic Equivalent) is well known as a unit to express strength of physical exercise. By using the heart rate, MET is calculated as follows,

$$MET = (HR - HRmin)/(HRmax - HRmin) \quad \text{[Karvonen Formula]} \qquad (1).$$

HRmin : heart rate in quiet,
HRmax : heart rate in the most heavy exercise

The MET is defined according with the strength of physical exercise roughly.(Table 1)

Table 1. Relation of MET and strength of physical exercise

40-50	light exercise (walking)
50-60	medium exercise (slow running)
60-85	stressed exercise
85-100	heavy exercise (professional level)

By selection of MET, suitable heart rate (HR) is calculated as follows:

$$HR = (HRmax - HRmin) \times MET + HRmin \qquad (2).$$

To keep a constant strength of physical exercise, BANSS supplies several advices to current exercise under conditions that are value and trend of HR. Table 2 and Table 3 show the selection of advices by these conditions.

Table 2. Selection of advices to keep a constant strength of physical exercise

Value of HR \ Trend of HR	Even or slow down	Rising up gradually	Rising up
$HR < HR_{by\_min\ MET}$	*Advice_1*		*Advice_3*
$HR_{by\_min.MET} < HR < HR_{Thr1}$	*Advice_1*	*Advice_2*	
$HR_{Thr1} < HR < HR_{Thr2}$	*Advice_2*		
$HR_{Thr2} < HR < HR_{by\_max.MET}$	*Advice_2*	*Advice_4*	*Advice_5*
$HR_{by\_max.MET} < HR$	*Advice_6*		

Table 3 List of six advices

	Advices
Advice_1	Pace up gradually
Advice_2	Keep pace
Advice_3	Pace down gradually
Advice_4	Pace down
Advice_5	Pace down quickly
Advice_6	Stop exercise now, have short rest

where $HR_{by\_min\ MET}$: Heart rate at minimum MET ,
$HR_{by\_max.MET}$: Heart rate at maximum MET ,
HR_{Thr1} : 1/3 ($HR_{by\_max.MET}$ - $HR_{by\_min\ MET}$) + $HR_{by\_min\ MET}$,
HR_{Thr2} : 2/3 ($HR_{by\_max.MET}$ - $HR_{by\_min\ MET}$) + $HR_{by\_min\ MET}$.

Fig. 3 and Fig. 4 show the time transition (blue line) of heart rate kept medium exercise (MET: 40 - 60) controled by advices of BANSS. In this experiment, each HRs are as follows:
in Fig. 3, (Male;23) $HR_{by\_min\ MET}$: 114, $HR_{by\_max.MET}$: 142, HR_{Thr1}: 123, HR_{Thr2}: 132,
in Fig. 4, (Male;32) $HR_{by\_min\ MET}$: 111, $HR_{by\_max.MET}$: 136, HR_{Thr1}: 119, HR_{Thr2}: 127.

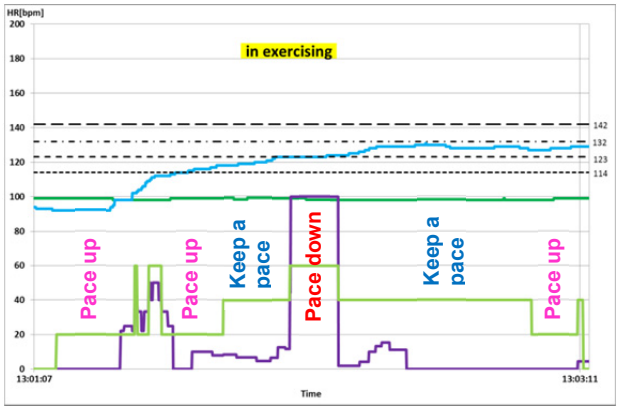

Fig.3. Heart rate(bule line) in medium exercise (MET : 40 - 60) controled by advices of BANSS (male, age: 23)

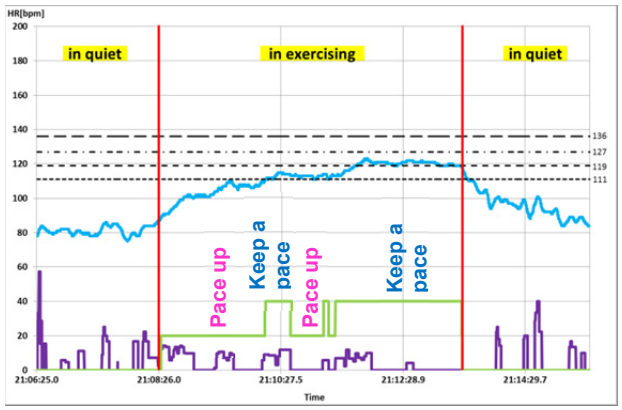

Fig.4. Heart rate(bule line) in medium exercise (MET: 40-60) controled by advices of BANSS (male, age: 32)

Subject in Fig.3 is same in Fig.2. The heart rate (blue line) has increased gradually in the previous half. In the latter half, the heart rate has kept within 123 – 132 bpm. BANSS is advising to the subject continuously by monitoring and analysing the time transition of heart rate. Especially, BANSS is changing advices frequently. It has been confirmed that constant medium exercise (MET : 40 - 60) is realized well in the latter half.

In Fig.4 shows the result by other subject (male; 32) in motion sequence; quiet, exercise and quiet. The subject switched on BANSS just at start of exercise, and switched off just at end of that. In exercising, it is confirmed that BANSS controls heart rate into the range of HR_{Thr1} and HR_{Thr2} by several advices.

4. Conclusions

It was confirmed to keep suitable physical strength in exercise by the interaction between BANSS and user that was the monitoring dynamic physical parameters of user and the advising exercise level to user. BANSS is useful tool to measure the physical parameters at various parts on body and estimate physical condition dynamically in motion. That does not become obstacle to various motions. By reconstructing BANSS as small and robust system, the application fields will spread more and more.

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