Physical Monitoring in Daily Life by Remote Body Area Network System

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Abstract. To spend daily life in high QOL, it is important to keep our health condition. Physical diseases are caused by various body parameters. People must get body parameter in daily life. Therefore people need wearable body area network system for getting body parameter in daily life. Authors made wearable body area network system which can get heart rate, SpO₂, body temperature, skin temperature, air temperature, impact and acceleration of waist, shoulder, both ankles and wrist. Moreover authors made some applications by using these parameters. This paper describes the wearable sensing network system, host system to monitor dynamic physical conditions of user at remote location and applications.

1. Introduction

People should spend in high QOL (Quality Of Life), however we sometime get physical diseases such as slipped disc and over tiredness. To prevent them we have to monitor own body parameter in daily life before getting them, and we have to care by ourselves. To share information with family and home doctor at remote location is important for week person. They can monitor the state of physical weak person by the information. To realize them, we develop wearable body area network system, high frequently asynchronous measurable system, and remote wireless communication system. The BAN and Remote Interactive Care system (RICS) can monitor and feedback for user’s life activities. This paper describes the BAN system, RICS system and Applications.

2. System Construction

2.1 Body Area Network system (BAN)

The figure 1 shows the construction of BAN. This system is constructed by 5 wearable modules (waist, shoulder, wrist, right ankle and left ankle). In this system, waist module works as host module, and other modules work as local nodes. They use 2 kind of wireless communications; blue lines show Bluetooth and green lines show Zigbee. Each module has PIC micro controller made by Microchip to control sensors and communication units. The shoulder module has earphone and sound module to inform physical and conditions methods of improvement to user.
2.2 Remote Interactive Care System (RICS)

Figure 2 shows the construction of RICS. This system is both direction data communication system. This system can report error to external when BAN detection body error. And this system can send advice to BAN user at remote location. This system is constructed with waist module, smart phone, cloud system and host PC. This system is connected to waist module and smart phone by Bluetooth of waist module and smart phone. This system sends and receives the data between waist module and smart phone by Bluetooth. Smart phone communicates with cloud system by 3G communication. This system sends and receives data between cloud system and smart phone by mail. Host system sends and receives data by accessing to cloud system.

3. Applications

3.1 Training Assistance by Monitor HR

This application leads user to exercise intensity by using the heart rate. User can keep adequate exercise by this application.

This application use Karvonen Formula, threshold and trend as index of making advice. Relationship of heart rate and exercise intensity is defined by Karvonen Formula. Figure 3 shows Karvonen Formula. HRmax mean 220-age. HRmin mean heart rate of normal time. HR mean max value or minimum value of threshold.
This application uses the Karvonen Formula for deciding the threshold of heart rate. In the Karvonen Formula, 40-50 [%] mean Light exercise (walking), 50-60 [%] mean Medium exercise (slow running), 60-85 [%] mean Stressed exercise and 85-100 [%] mean Heavy exercise (athlete level).

\[
EI(\%) = \frac{(HR - HR_{\text{min}})}{(HR_{\text{max}} - HR_{\text{min}})} \times 100 \quad \text{[Karvonen Formula]}
\]

\[HR_{\text{min}} : \text{heart rate in quiet} \quad HR_{\text{max}} : \text{heart rate in the most heavy exercise}\]

**Figure 3.** Karvonen Formula

Thresholds value are calculated by the Karvonen Formula stated above. It is obtained by splitting the value between max value (max) and min value (min) into three. High splitting value called thr1. Low splitting value called thr2. For example, if max value is 145 and min value is 120, splitting values are 136(thr1) and 128(thr2). Figure 4 shows this example.

Index of the trend are [HR < min], [min < HR < Thr1], [Thr1 < HR < Thr2], [Thr2 < HR < Thr max], [Thr max < HR].

**Figure 4.** Thresholds(max=145, min=120, Thr1=136, Thr2=128)

Trend mean change of heart rate. Trend and threshold judge kinds of advice. Thresholds are classified three parts. They are as falling trend or flat, as mild trend and as steep trend. The maximum trend calculation of data acquisition for heart rate is three seconds. Index of the trend are \[\text{trend} \leq 0\], \[0 < \text{trend} < 2\] and \[2 \leq \text{trend}\]. Figure 5 (a) shows advice generation by heart rate of existing range and trend.

Figure 5 (b) shows kinds of sound advice. This experiment feeds back to user by six kinds of advice. They lead to proper exercise subjects.

**Figure 5.** Kinds of Advice

3.1.1 Experimental Method

Experiment is conducted on treadmill. The experiment takes 2 patterns for proving effectiveness of the system. 2 patterns are training without advice and training with advice. This paragraph proves validity by comparing experimental results. Experiment time schedule is as follows. Training without advice; Firstly, a subject waits for 1 min. Secondly, a subject runs for 10 min by 7km/h (no advice). Finally, a subject waits for 5 min. Training with advice; Firstly, Waiting for 1 min. Secondly, user runs for 10 min by advised running. Finally, user waits for 5 min.
3.1.2 Impact on The Movement by Sound Advice

Table 1 shows body parameter of subjects. All subjects are men.

| Subject | Age | Weight | Normal Heart Rate | Threshold max | Threshold min |
|---------|-----|--------|-------------------|---------------|---------------|
|         |     |        |                   | 145           | 120           |
| A       | 24  | 67kg   | 70bps             |               |               |
| B       | 22  | 57kg   | 64bps             | 144           | 117           |

Colours on figure 6 (b) and figure 7 (b) are kinds of advice. Proper advices can lead heart rate in threshold. Percentage of HR on threshold of training without advice is 5.4% in case of subject A. Percentage of HR on threshold of training with advice is 84.1% in case of subject A. Percentage of HR on threshold of training without advice is 4.2% in case of subject B. Percentage of HR on threshold of training with advice is 80.3% in case of subject B. Both subjects are better. This result proves that advices lead user to aim heart rate zone. This paragraph proves effectiveness of the system by experimental results.

![Figure 6](image1)
(a) Training without advice  
(b) Training with advice  
**Figure 6.** Comparison of no advice and advising to subject A

![Figure 7](image2)
(a) Training without advice  
(b) Training with advice  
**Figure 7.** Comparison of no advice and advising to subject B

3.2 Estimation of Body Inclination in Walking

This application shows body inclination to user. Acceleration sensor of waist module gets body inclination and body swing. Acceleration sensor of ankle modules gets gap of landing impact of both ankles. Figure 8 shows the structure of the acceleration axis of each module. The tendency and degree of inclination of the body are judged from a measurement result. Table 2 and Figure 9 show the types of the tendency of inclination and how to determine it.

In this system, the tendency of inclination is judged from Table 2 The case that the body inclines to the same side as the foot of a greater landing impact is set to "Trunk Distortion..."
This type is the type that inclination of the trunk causes a greater landing impact to the foot. Then the case that the body inclines to the opposite side as the foot of a greater landing impact is set to "Tread Reaction Type". This type is the type that the gap of landing impact causes the inclination of the body.

Figure 9. 3-Tendency Type

3.2.1 Experimental method
Experiment time schedule is as follows. Firstly, a subject stood on treadmill for 30 seconds. Secondly, a subject walked for 20 minutes at 4km/h. Finally, a subject stopped walking and stood for 5 minutes.

The experiment was carried out three times. Subject A was once, subject B was one times, and subject C was once. Table 3 shows body parameter of subjects. All subjects are men.

| Subject | Age | Height(cm) | Weight(kg) | Smoking | Sport experience          |
|---------|-----|------------|------------|---------|---------------------------|
|         | 22  | 169        | 56         | No      | Baseball player for 8 years |
|         | 22  | 174        | 57         | No      | None                      |
|         | 22  | 168        | 59         | Yes     | Football player for 8 years |

3.2.2 Judgment Result
The processing result is shown below. Judgment of tendency is expressed by bar chart in each section. A red stick in two upper graphs expresses the inclination of right side, and a blue stick in them expresses the inclination of left side. Further, a red stick in the lower left graph expresses Trunk Distortion Type, and a blue stick in it expresses Tread Reaction Type.

Figure 10 shows the first experimental result of subject A. The burden placed on his left ankle is heavier than his right ankle. However, the inclination of his body is small, there is no trend. Moreover, the swing of his body is small as a whole. To summarize these results, this system determines that the walking posture of the subject A is good balance.

Figure 11 shows the experimental result of subject B. The burden placed on his left ankle is heavier than his right ankle. His body leans to the left. Moreover, the swing of his body is large. To summarize these results, this system determines that the walking posture of the subject B is Trunk Distortion Type at the rate of 87%. In addition, the burden of his body becomes bigger because the swing of his body is large.

Figure 12 shows the experimental result of subject C. The burden placed on his right ankle is heavier than his left ankle. His body leans to the left. However, the swing of his body is small. To summarize these results, this system determines that the walking posture of the subject C is Tread Reaction Type at the rate of 77%. 

Table 2 Tendency of Inclination

| Body Inclination Landing Impact | Right | Left |
|--------------------------------|-------|------|
| Right                          | Trunk Distortion Type | Trend Reaction Type |
| Left                           | Trend Reaction Type   | Trunk Distortion Type |
4. CONCLUSION

BAN can get body information in daily life. RICS share information getting by BAN to Family, doctor and trainer. Applications can do training assistance by monitor and estimation of body inclination in walking. They system can lead people to better movement. People can spend in high QOL by using this system.

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