Dynamic Measurement of Physical Conditions in Daily Life by Body Area Network Sensing System

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Abstract. This paper shows the measurement system to monitor physical conditions dynamically in dairy life. The measurement system for physical conditions in motion must be wearable and wireless connected. Body area network sensing system (BANSS) is a kind of the system to realize the conditions. BANSS is the system constructed with host system and plural sensing nodes. Sensing node is constructed with sensors, analogue/digital convertor(ADC), peripheral interface component(PIC), memory and near field communication device(NFCD). The NFCD in this system is Zigbee. Zigbee is the most suitable to construct wireless network system easily. BANSS is not only the system to measure physical parameters. BANSS informs current physical conditions and advises to keep suitable physical strength. As an application of BANSS, the system managing heart rate in walking is shown. By using this system, users can exercise in condition of a constant physical strength.

1. Introduction
To keep and enhance human quality of life (QOL), it is important to know physical condition well continuously. The condition is depended on physical activities in daily life. The state 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 networked measurement system is the most suitable system to measure the physical condition dynamically and continuously. That system collects physical parameters on several measuring points on body. In this paper, that system is called Body area network sensing system(BANSS). Concerning to BANSS, there are several kinds of system [1-21]. The system 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, the system will transmit the measurement data and the objective information of physical condition to family or home doctor of user.

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.
Sensing node is mainly constructed with some sensors, Analog-Digital Converter (8 channels, 10 bits 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. The sensing node on ear includes the sensors for heart rate, SPO2 and body temperature. The sensing node on waist includes the sensors for acceleration and skin temperature. The sensing nodes on knees include the sensors for acceleration. And the sensing nodes on ankles include the sensors for acceleration and impact. Fig.2 shows an example of the sensing node on ear. The main role of sensing node is the detection, analysis and transmission of physiological parameters which express physical conditions in motions.

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. Fig.3 shows the host system attached on body of user.
3. Application : Realization of Constant Strength to Body by Monitoring Heart Rate

As an application of body area network sensing system (BANSS), we have tried to realize constant strength by monitoring heart rate. Fig.4 shows the time transition of heart rate (blue line) in a motion sequence of quiet, walking, quiet, running and quiet (Lab. student ; male, age:21). By using BANSS, dynamic situation of heart rate is observed on line like this.

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.

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,
\[ MET = \frac{(HR - HR_{min})}{(HR_{max} - HR_{min})} \]  
[Karvonen Formula]  

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

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

| MET | 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,

\[ HR = (HR_{max} - HR_{min}) \times MET + HR_{min} \]  
(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.

| Trend of HR | Value of HR | Even or Slow down | Rising up gradually | Rising up |
|------------|------------|-------------------|---------------------|----------|
| HR < HR_{by\_min\_MET} | Advice_1 | | | |
| HR_{by\_min\_MET} < HR < HR_{Thr1} | Advice_1 | Advice_2 | | | Advice_3 |
| 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 |

where

\[ HR_{by\_min\_MET} : \text{Heart rate at minimum MET}, \]
\[ HR_{by\_max\_MET} : \text{Heart rate at maximum MET}, \]
\[ HR_{Thr1} : \frac{1}{3} (HR_{by\_max\_MET} - HR_{by\_min\_MET}) + HR_{by\_min\_MET}, \]
\[ HR_{Thr2} : \frac{2}{3} (HR_{by\_max\_MET} - HR_{by\_min\_MET}) + HR_{by\_min\_MET}. \]

Fig.5 shows the time transition (blue line) of heart rate kept medium exercise (MET : 40 - 60) controled by advices of BANSS. In this experiment, HR_{by\_min\_MET} is 114, HR_{Thr1} is 123, HR_{Thr2} is 132 and HR_{by\_max\_MET} is 142.
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. It has been confirmed that constant medium exercise (MET : 40 - 60) is realized well in the latter half.

4. Conclusions

Physical condition in quiet at hospital or home shows only an aspect of health at that time. Actual health monitoring must be done in activities of daily life like walking, running, sitting and so on. Physical conditions in daily life change dynamically. This paper shows the measurement system monitoring physical conditions in various motions in daily life by body area network sensing system (BANSS). BANSS is the wearable system which sensing nodes are connected by near field wireless communication. That does not become obstacle to various motions. BANSS will estimate qualitative physical conditions of body by the fusion of heterogeneous and homogeneous measuring data. In addition to them, by using SVHI, BANSS shows current physical conditions as quantitative and qualitative data, and gives advices to keep suitable MET. It is considered that BANSS realizes various kinds of applications. By reconstructing BANSS as small and robust system, the application fields will spread more and more.

5. References

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