Visualizing Physiological Information Based on 3DCG

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The purpose of this study is to propose a new method for visualizing bio-information. In this visualization, 3DCG avatar motion represents human motion captured with high accuracy by an optical motion capture system. Health conditions are represented by the color or size of avatar organs. The image effect is also used to represent health conditions. A characteristic of the proposed method is intuitive recognition of health conditions. In this visualization, multiple biosignals can be used and health conditions of a number of people can be represented. The visualization method can apply to synchronized analysis of heart rate variability, muscle activity and motion.
Key words: Visualization, Motion Capture, Biosignal, 3DCG, Physiological Information

1. Introduction

Three-dimensional imaging techniques in medical science are applied to visualize non-observable organs or tissues for diagnosis and treatment. Examples of such techniques are computed tomography (CT), X-ray imaging, magnetic resonance imaging (MRI), fiber scope and ultrasonic imaging (Lysdahl and Borretzen, 2007). The balance of autonomic nervous activity, relaxation effect, sleep stage, muscle activity, and health conditions are estimated based on analysis of bio-signals. Several representation methods such as tachograms, mapping charts, and tables are used for visualizing results derived from bio-signal analysis. Motion analysis is applied to sports activity, evaluation of work posture, and diagnosis of the effect of rehabilitation. Video image analysis is generally applied to motion analysis. There are few examples of integrated analysis of biosignals and human motion. One is to analyze human motion using electromyograms (EMG) and video imaging.

The purpose of this study is to propose a new method for visualizing bio-information. In this visualization, 3DCG avatar motion represents human motion captured with high accuracy by an optical motion capture system. Health condition is represented as color or size of avatar organs. The image effect is also used to represent health conditions. There are a few examples which represent human motion synchronized with EMG signals. In these visualizations, the representation of health conditions is inadequate, i.e., simple cylinder body model (Seri *et al.*, 2000; Urawaki *et al.*, 2004; Inaba *et al.*, 2006).

The key characteristics of the proposed system are its highly accurate estimation of health conditions and intuitive recognition of health conditions. In this visualization, multiple biosignals can be used and the health conditions of a number of persons can be represented. The visualization method can be used for synchronized analysis of heart rate variability, muscle activity and motion. The autonomic nervous response and the muscle activity in relation to the change in transitional motion can be presented at the same time. A wide application is possible because the visualization method can present intuitive representations of health conditions in daily life for multifaceted evaluation of physiological conditions.

2. Method

An outline showng the proposed visualizing system is presented in Fig. 1. Reflection markers are captured using an optical motion capture system (EVaRT4.7: Motion Analysis, USA) at 60 [fps: frames per second]. Human motion is estimated from the time series of marker positions. Surface electromyogram (SEMG) and electrocardiogram (ECG) are collected using a telemetric portable bioamplifier (BA1104, TU: Digitex lab. Co., Ltd, Japan) to estimate muscle activities and heart rate variability. These data were stored on a Pentium PC via a 16 [bit] A/D converter using the analogue input function of EVaRT. A sampling trigger was generated at capturing intervals by the motion capture system with a sampling frequency of 1200 [Hz].

Percentage of maximum voluntary contraction (%MVC) and standardized instantaneous heart rate were used as the health condition parameters, which make easy comparison possible among a number of people without the effects of personal differences. The procedures for visualizing %MVC and standardized iHR are as follows.

A. SEMG

The methods used for signal processing and visualizing SEMG are shown in Fig. 2.

1) Full-wave rectification is applied to the sampled SEMG signal and calculated.

2) Rectified SEMG is resampled at 60 [Hz].

3) Low-pass filter is applied to the resampled SEMG using the moving average method whose window width is 20 frames (0.33 [s]). The amplitude is defined as voluntary contraction.

4) %MVC [%], which is the rate of voluntary contrac-

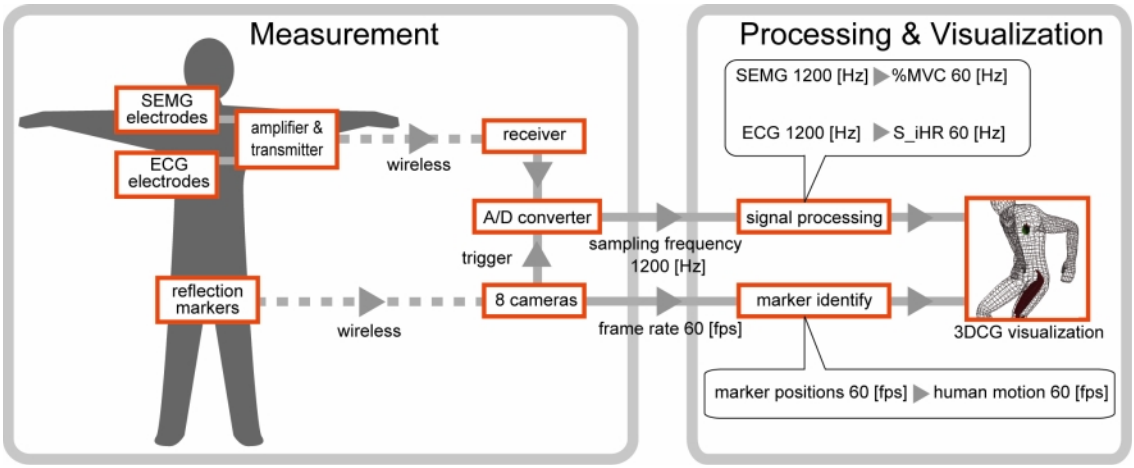

Fig. 1. Outline of proposed visualizing system.

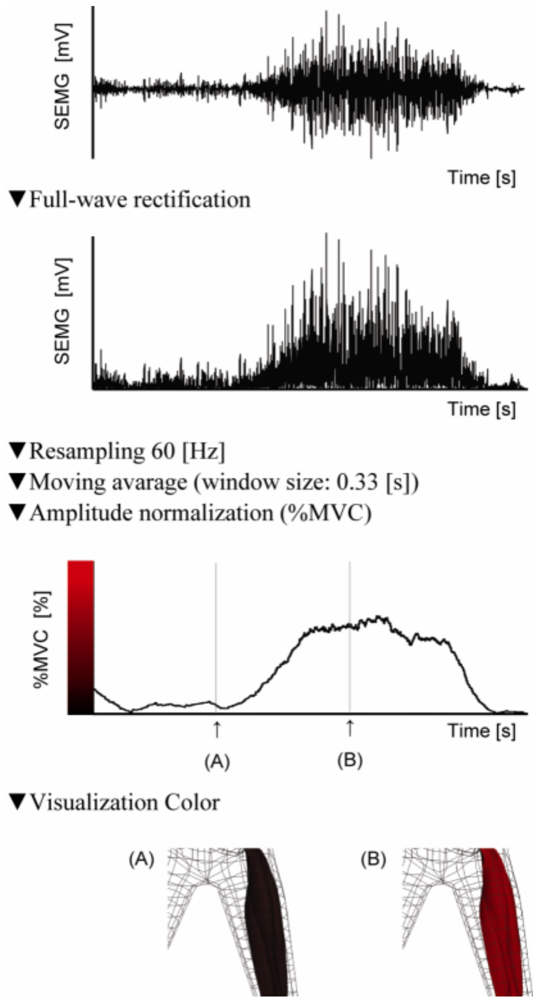

Fig. 2. Method of signal processing and visualizing of SEMG.

tion and maximum voluntary contraction, is calculated.

5) %MVC is assigned to the tone of color of the targeted muscle. The color of the muscle model is dark when the %MVC is low (model A). On the other hand, the color of the muscle model is vivid when the %MVC is high (model B).

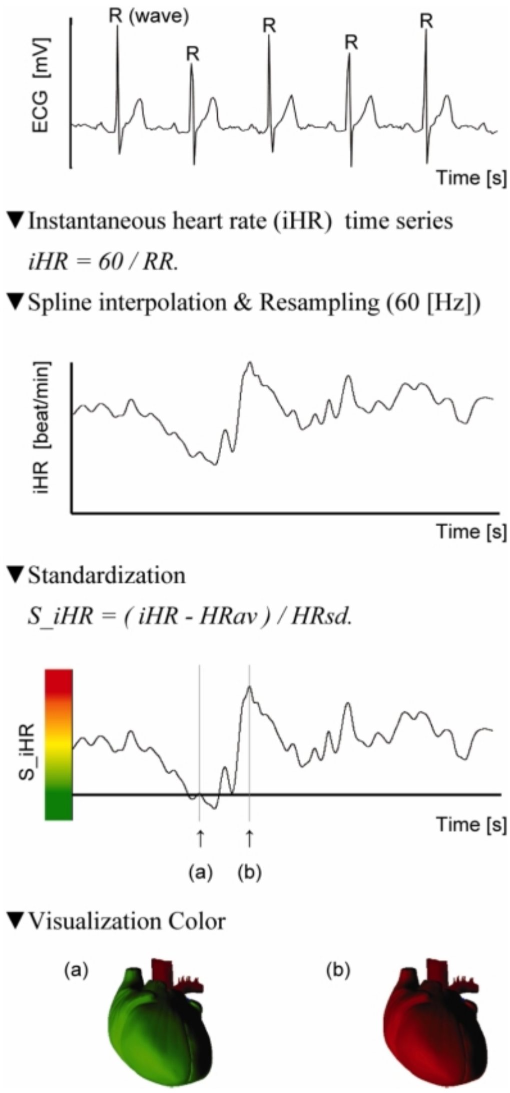

Fig. 3. Method of signal processing and visualizing of ECG.

B. ECG

The method of signal processing and visualizing of ECG are shown in Fig. 3.

1) Instantaneous heart rate (iHR [bpm: beats per

Table 1. Anthropologic data and physiological characteristics of experimental subjects.

	A	B	C	D	E
Height [cm]	160	161	175	180	168
Weight [kg]	50	47	65	61	60
HRave [bpm]	73.5	75.3	82.5	81.2	65.2
HRsd [bpm]	2.3	2.4	3.2	2.6	2.5
Motion	Aerobic	nurse-care1 assisted	nurse-care1 service	nurse-care2 assisted	nurse-care2 service

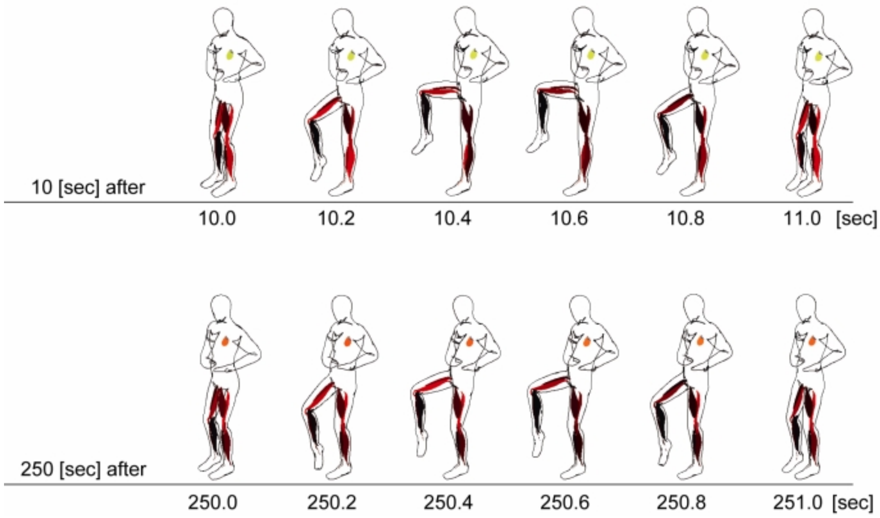

Fig. 4. Visualization results of health condition during aerobic dance.

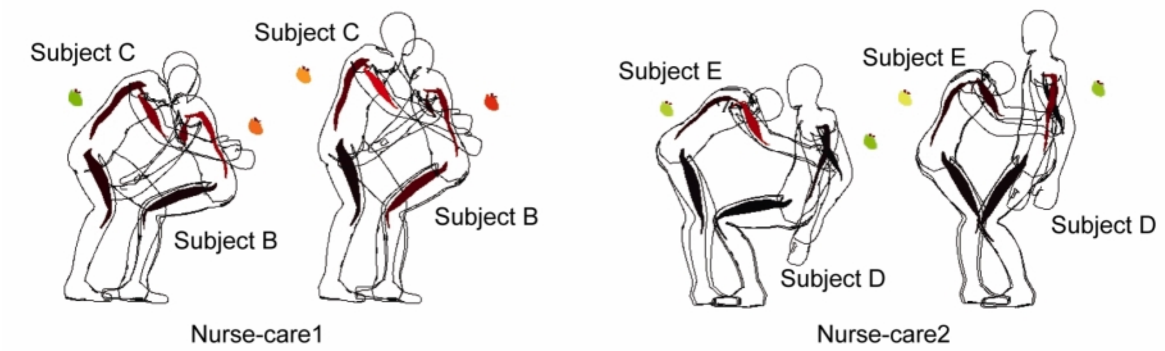

Fig. 5. Visualization results of nurse-care motions performed by two pairs.

minute]) is calculated from the R-R interval (RR [s]) of ECG in accordance with the following equation:

$$\mathrm{iHR} = 60/\mathrm{RR}.$$

2) The iHR time series is interpolated by the spline method. This interpolated time series is resampled at 60 [Hz].

3) To calculate S_iHR, average and standard deviation are calculated from the iHR time series measured in the resting condition. S_iHR is calculated by

$$\mathrm{S\_iHR} = (\mathrm{iHR} - \mathrm{HRave})/\mathrm{HRsd},$$

where HRave is the average and HRsd is the standard deviation of the time series of iHR during the resting condition.

4) S_iHR is assigned to the color of the heart model. Sympatho-vagal balance controls heart rate variability. Parasympathetic nerves decelerate the heart rate and sympathetic nerves accelerate it (Hainsworth, 1995). Warm color is associated with sympathetic nerves and cool color with the parasympathetic nerves. The S_iHR is neutral (average iHR of during resting condition) so the color of the left heart model (model a) is green. The S_iHR is high so the color of the right heart model (model b) is red (warm color).

3. Visualization Results

3.1 Experimental condition

To evaluate the usefulness of the proposed system, two experiments were performed.

1) Aerobic dance (knee-up 300 [sec]: tempo 140 [bpm])

2) Nurse-care motion (passive standing)

Anthropologic data and physiological characteristics of experimental subjects are described in Table 1. Subject A performed an aerobic dance and nurse motions were performed by other subjects. Subjects B and D acted as assisted persons.

In the aerobic dance experiment, the SEMG electrodes were positioned on the front of the thigh (vastus medialis), back of the thigh (biceps femoris), front of the shin (tibialis anterior) and back of the shin (gastrocnemius) (Zipp, 1982). In the nurse-care motion, the SEMG electrodes were positioned on the right arm muscle (biceps brachii), waist muscle (erector spinae), and right leg muscle (vastus medialis).

3.2 Results

The results of visualizing the health condition during the aerobic dance are shown in Fig. 4. The health conditions at 10 [sec] after starting (upper figure) and at 250 [sec] after starting (lower figure) are shown.

These six avatars represent six motions, muscle activities and instantaneous heart rate at 0.2 [sec] intervals for 1 [sec] in this figure. Muscle color is indicated in red and black when %MVC is 0% and 40%, respectively. Color of the heart is green and red when S_iHR is 0 and 40, respectively. The muscle activities of the front thigh of the right leg and back thigh of the left leg were respectively increased. The difference caused by continuance time was shown in knee position and in activity of shin muscle. The heart rate was increased 250 [sec] later. But heart rates were constant from 10 [sec] to 11 [sec]. The effects of aerobic dance can be intuitively presented. The muscle activities of whole leg, exercise volume reflecting heart rate and motion can be represented comprehensively.

Nurse-care motions performed by two pairs are shown in Fig. 5. Muscle color is indicated in red and black when %MVC is 0% and 30%, respectively.

Color of heart is green and red when S_iHR is 0 and 10, respectively. It is clear from the avatar motion seen in the figure on the right that the service person is making effective use of his/her knee motion. The muscle activity and heart rate of the service person and the assisted person in the figure on the left were higher than in the one on the right. The mutual relationship between the assisted person and service person can be present comprehensively. The relationship between nurse-care motion and physical workload of two persons can be evaluated intuitively.

4. Conclusion

We have proposed a new method for visualizing bio-information, which represents muscle activity and heart rate variability with several persons synchronized with motion.

In the experimental results, it was confirmed that our method can present multi physiological conditions, such as muscle activity and heart rate variability of multiple persons dynamically and intuitively. This is a very large advantage for analysis of workload of cooperative motion compared with the conventional motion analysis method or bio-signal analysis.

This system can be used as a support technology to obtain new findings in the field of ergonomics, for example, in evaluating biological load in daily living activities or at production sites.

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