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Quantification of Dance Movement by Simultaneous Measurement of Body Motion and Biophysical Information

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Abstract: The purpose of this research is a quantitative analysis of movement patterns of dance, which cannot be analyzed with a motion capture system alone, using simultaneous measurement of body motion and biophysical information. In this research, two kinds of same leg movement are captured by simultaneous measurement; one is a leg movement with given strength, the other is a leg movement without strength on condition of basic experiment using optical motion capture and electromyography (EMG) equipment in order to quantitatively analyze characteristics of leg movement. Also, we measured the motion of the traditional Japanese dance using the constructed system. We can visualize leg movement of Japanese dance by displaying a 3D CG character animation with motion data and EMG data. In addition, we expect that our research will help dancers and researchers on dance through giving new information on dance movement which cannot be analyzed with only motion capture.

Keywords: Motion measurement, electromyography (EMG), animation.

1 Introduction

Recently, it has been frequently studied to analyze dance movement with motion capture, but some movement is unable to be analyzed by motion data alone. Systematical researches on dance movement are rarely carried out using several kinds of data captured by simultaneous measurement of body motion and biophysical information.

In this research, we aim to quantitatively analyze characteristics of dance movement using the biophysical data such as an electromyogram (EMG). Also, it is expected to explicate the influences of proficiency of dance, differences from age and differences from sexual distinction on dance performance from biophysical information and body motion.

We are able to visualize leg movement by displaying a 3D CG character animation with motion data and EMG data. Thus, we expect that our research could help dancers and researchers on dance through giving new information on dance movement which cannot be analyzed with motion capture alone.

There are several researches on analyses of movement through simultaneous measurement of body motion and biophysical information, for instance, the learning environment for sport-form training[1], biomechanical analysis of ballet dancers[2], and behavior capture system[3]. However, quantitative analysis on dance movement has not been accomplished yet. There is a research which extracts a target motion from motion captured dance data[4]. Also, skillfulness of the dancing is investigated by calculating typical style of dancing called Okuri[5].

In this paper, we paid attention to leg movement which is very important for most of the body movement. We introduce a method of simultaneously measuring and visualizing body motion and biophysical information.

2 Simultaneous meaurement system of body motion and biophysical information

In this research, we capture data of leg movement by using optical motion capture and EMG instrument simultaneously. Fig. 1 shows a simultaneous measurement system of body motion and biophysical information. To obtain motion data, MAC3D (MotionAnalysis Corp.) at Ritsumaikan University is used. In this system, we can use an eye tracking system called Eye Mark Recorder (EMR) and an EMG instrument as equipment for biophysical information measurement. However, EMR system is not used in this paper.

Motion data and EMG are measured simultaneously with EVaRT software, and a measured analog EMG signal is transformed into ANC format digital data by an A/D converter. Motion data measured by motion capture system is recorded in TRC data format.

2.1 Optical motion capture

The optical motion capture system employs video cameras to track the motion of reflective markers attached to joints of the actor's body. Three to sixteen (or more) cameras are necessary for full-body motion capture. The optical motion capture system uses LED's mounted around the camera lens. In this system, the centers of the marker images are matched from the various camera views using

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triangulation to compute their frame-to-frame positions in 3D space. Several problems often occur during the tracking process, including swapping of markers, noisy or missing data and false reflections.

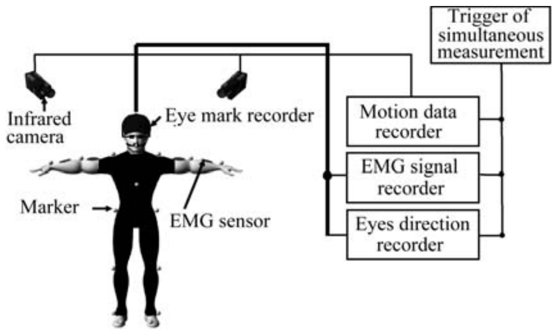


Fig. 1 Configuration of the system

Fig. 2 Optical motion capture

Fig. 2 shows appearance of motion capture for dance movement.

2.2 EMG

EMG is a signal of an electrical potential generated in accordance with movement of muscles, and is measured by electrodes attached on skin surface. Amplitude of EMG signal is almost proportional to the scale of muscle force. To acquire maximum muscle force, increasing frequency of excitement is needed by mobilizing alpha motoneuron. While maximum muscle force brings out, amplitude of EMG signal is increased gradually in proportion to the force. The relation of EMG signal and the force can be used in order to analyze various human body movements. Recording EMG signal needs electrodes, an amplifier and a data recording device. EMG signal is obtained by A/D converting data amplified by the amplifier. In this research, we used SYNA ACT MT11 system (NEC Corp.)(see Fig. 3).

Because original EMG signal obtained by the equipment is full of high frequency noise, we have to employ some noise reduction techniques like low pass filtering. Also we have to convert original signal into a signal which is proportional to the activities of muscles. Rectification of the signal or RMS (root mean square) of the signal are usually used for the purpose.

Fig. 3 EMG equipment

3 Experiments on basic body movements

In this research, we carried out experiments on basic body movements in legs with simultaneous measurement of body motion and EMG signal. We measured some basic movements of the leg such as walking movements, stretching, sitting and twisting movements. In this paper, we describe the method and result of experiment on walking movements and sitting movements.

3.1 Method of experiment

We carried out measurements on two kinds of movements; one is walking movement and sitting movement with given strength and the other is walking movement and sitting movement without strength. These body movements are shown in Figs. 4 and 5.

(a)

(b)

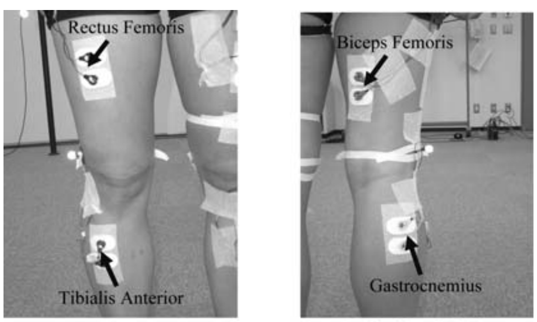
Fig. 4 Walking movements: (a) walking movement without strength , and (b) walking movement with given strength

(a)

(b)

Fig. 5 Sitting movements: (a) sitting movement without strength, and (b) sitting movement with given strength

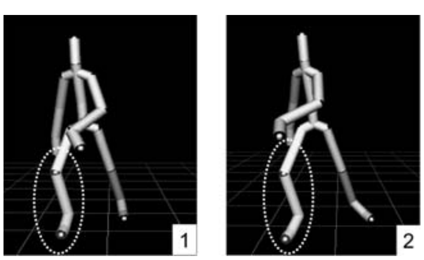
In order to capture data of walking movement and sitting movement, we experimented on a woman dancer having 15 years of experience. The subject is attached 32 markers on the body in order to capture motion data, and is adhered four EMG electrodes on the front and back of a right leg (see Fig. 6). According to the literature on EMG[6], the attaching places of EMG electrodes are fixed on the following four muscles: Rectus Femoris, Tibialis Anterior, Biceps Femoris and Gastrocnemius.



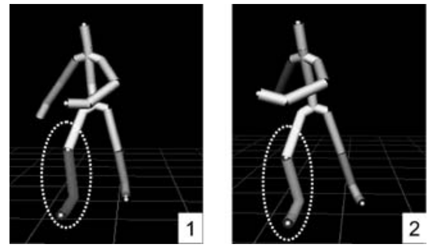
Front of the right leg   Back of the right leg

Fig. 6 Attaching places of EMG electrodes

In order to display the activation of EMG by character animation, we analyzed by choosing the 2 leg muscles (Rectus Femoris and Tibialis Anterior). We recorded data by adjusting the sampling rate of motion capturing to 60 Hz, and the EMG measurement to 1 020 Hz.

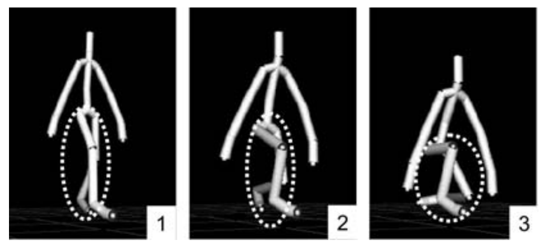


(a)

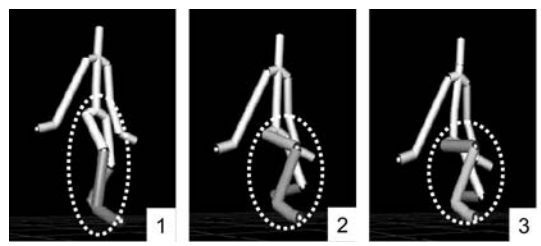


(b)

Fig. 8 CG character animation of motion data and EMG signal on walking movement: (a) walking movement without strength, and (b) walking movement with given strength



(a)



(b)

Fig. 9 CG character animation of motion data and EMG signal on sitting movement: (a) sitting movement without strength, and (b) sitting movement with given strength

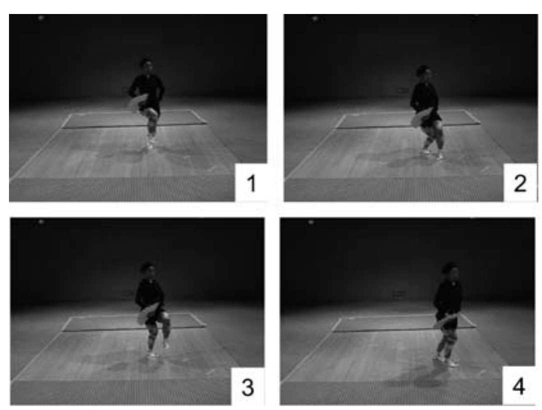


Fig. 10 Yujo of Hokusyu

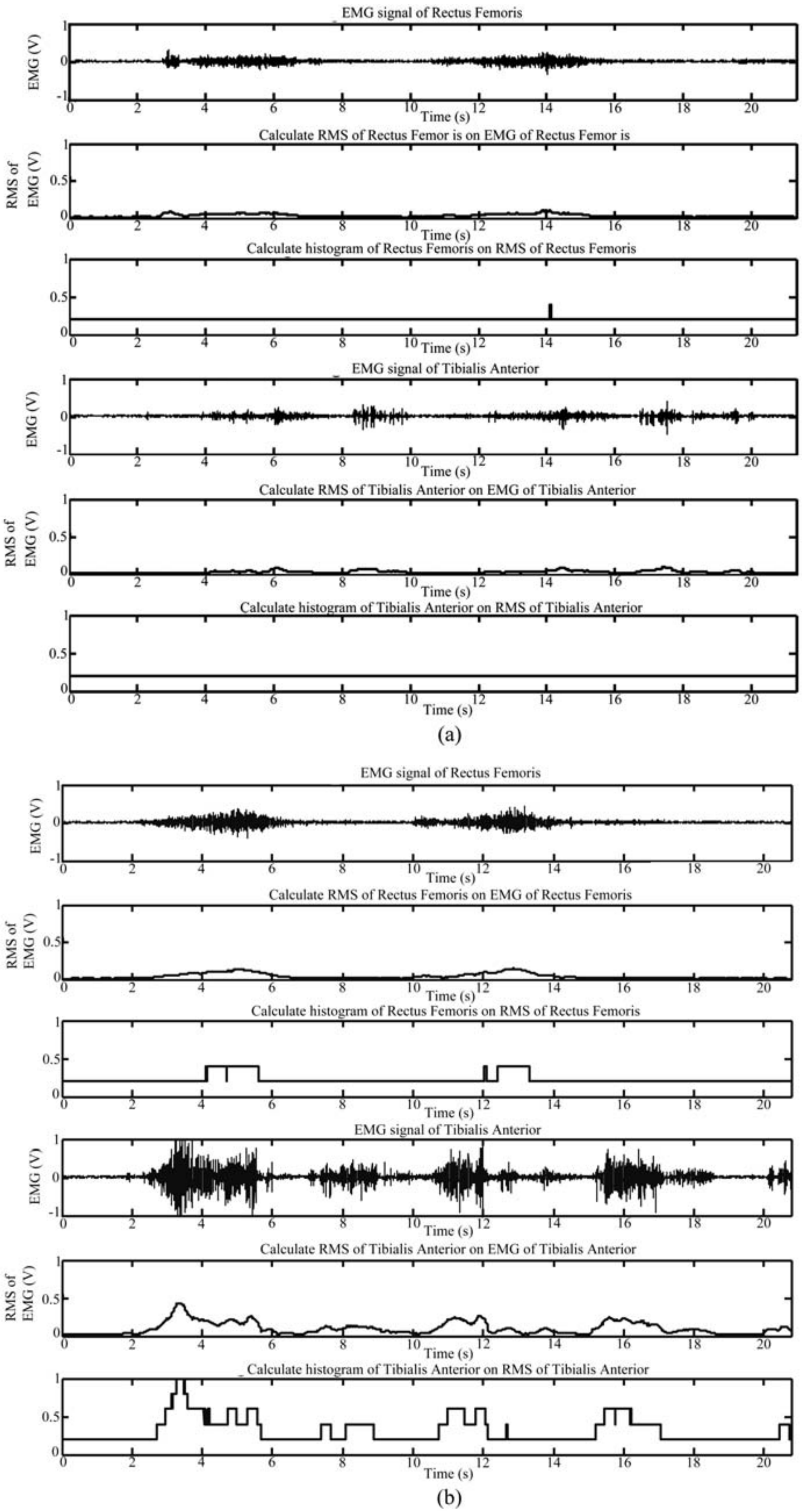


Fig. 7 Calculation of RMS on walking movement EMG signal: (a) walking movement without strength, and (b) walking movement with given strength

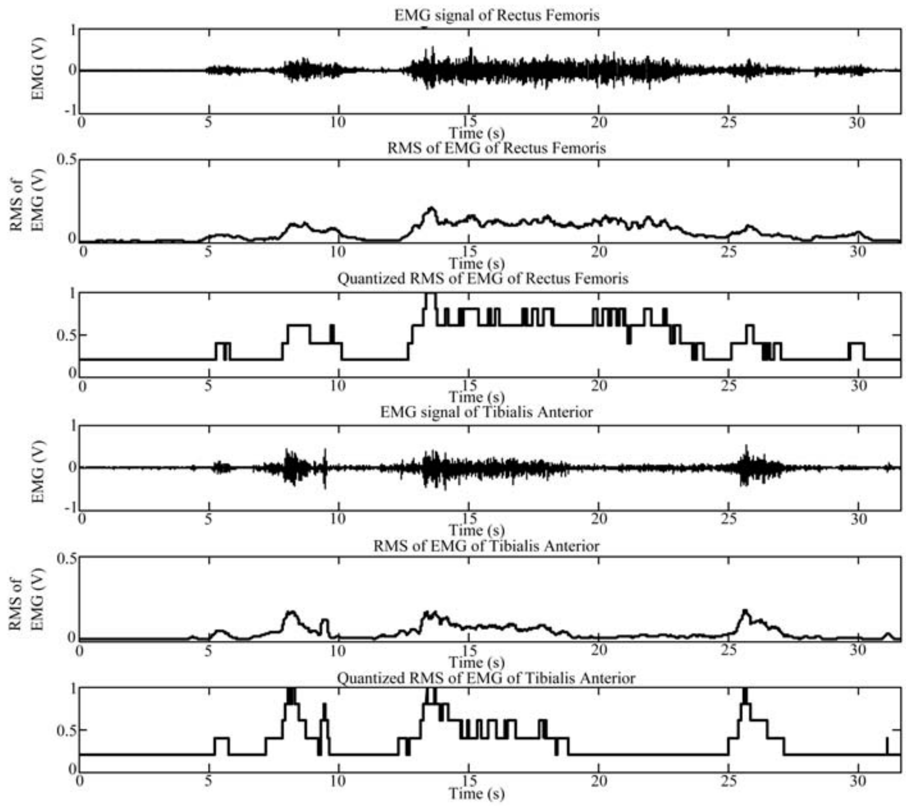


Fig. 11 Calculation of RMS on Yujo of Hokusyu EMG signal

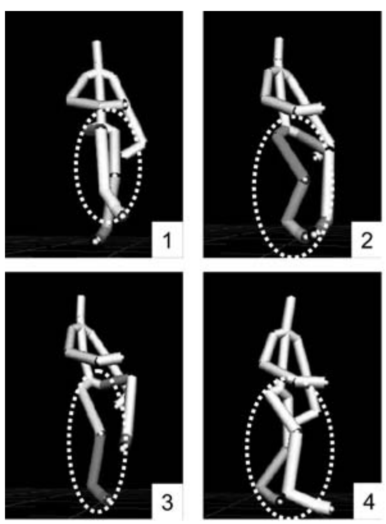


Fig. 12 CG character animation of motion data and EMG signal on Yujo of Hokusyu

3.2 Result and discussion of experiment

Fig. 7 shows the process of analyzing EMG signals of Rectus Femoris and Tibialis Anterior of the right leg on walking movements. Firstly, we calculated Root Mean Square (RMS) of EMG signals according to the activation of muscles. The RMS signal was quantized into 5 levels. Then we made a CG character animation, which is drawn by an OpenGL program, coloring character's legs in accordance with quantized RMS data.

Fig. 8 shows snapshots of CG character animation with generated colors. We learned that on a condition of given strength color became deeper than without strength in proportion to activation of EMG as shown in Fig. 8. Figures indicated by letters 1 and 2 in Fig. 8 (a) are corresponding to figures indicated by 1 and 3 in Fig. 4 (a), also letters 1 and 2 in Fig. 8 (b) are corresponding to 1 and 3 in Fig. 4 (b) respectively. As a result, we found that the difference of walking movement, which is not noticeable in (a) and (b) in Fig. 4, is more obvious through displaying EMG information on the CG character.

Next, Fig. 9 shows snapshots of CG character animation with generated colors on sitting movements. Letters 1, 2 and 3 in Fig. 9 (a) are corresponding to 1, 2 and 3 in Fig. 5 (a), also letters 1, 2 and 3 in Fig. 9 (b) are corresponding to 1, 2 and 3 in Fig. 5 (b) respectively. In case of sitting movement without strength in Fig. 9 (a), muscle of Tibialis Anterior is not activated. As seen in letter 2 of Fig. 9 (a), only Rectus Femoris is activated. In case of sitting movement with strength in Fig. 9 (b), Tibialis Anterior in letters 1, 2 and 3 is activated, while Rectus Femoris is also activated in letters 2 and 3. As a result, we learned that under condition of sitting movement with strength, we can keep sitting posture using Tibialis Anterior which controls excessive strength as a brake device.

4 Experiments on Japanese dance

Next, we carried out similar experiments on traditional Japanese dance, Nihonbuyo, with simultaneous measurement of body motion and EMG signal.

4.1 Method of experiment

We measured the traditional Japanese dance work named Hokusyu using the constructed system. In Hokusyu, one dancer plays several roles such as a warrior, a coachman, a merchant, etc. and acts twenty one performances by oneself. In this research, we measured eight performances from the whole Hokusyu's performances.

The subject of this experiment is the Hanayagi style dancer who has a forty years career. We attached thirty two markers and four electrodes on the body of the subject, and recorded eight performances, three times for each.

4.2 Result and discussion of experiment

Here, we describe the result of experiment on a part of Yujo in Hokusyu (see Fig. 10). Yujo is a woman who plays a dance and song in the era of Edo.

Fig. 11 shows the process for coloring of CG character legs by analyzing EMG signals of Rectus Femoris and Tibialis Anterior of the right leg on Yujo of Hokusyu. Figures indicated by letters 1, 2, 3 and 4 in Fig. 12 correspond to 1, 2, 3 and 4 in Fig. 10, respectively.

In the figure with letter 2 of Fig. 12, the dancer keeps the posture using Rectus Femoris much more than Tibialis Anterior. The fact is shown that the dancer uses knees and waist together. In the figure with letter 3 of Fig. 12, the dancer keeps the posture using Tibialis Anterior much more than Rectus Femoris. The dancer balances herself on the right leg. We found that Tibialis Anterior which controls movements of ankles as a brake device prevents the dancer's body from falling.

5 Conclusion and future work

We investigated quantification of dance movement by simultaneous measurement of body motion and biophysical information. For the above objective, we constructed a simultaneous measurement system with optical motion capture and EMG equipment. This system enabled us to record basic movements of legs while both the motion data and EMG are visualized on CG character animation. We can expect that our research will help dancers and researchers on dance through giving new information on dance movement which cannot be analyzed with motion capture alone.

In the future, we will measure the way of leg movements of veteran dancers, especially for comparing leg movement skills quantitatively by recording leg movements between masters and beginners. Furthermore, we will investigate the skill of leg movements with EMG equipment and force plate simultaneously.

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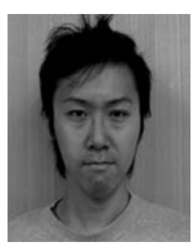

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