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Development of the Learning Environment for Sport-form Education with the Visualization of Biophysical Information

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Abstract

For sport-form learning, non-visible information, such as intensity or timing of muscular contraction, is important as well as visible body motion. In this paper, we propose a system that can provide both visible and non-visible information of sport form. The proposed system acquires subject's motion and muscular activities with motion capturing system and electromyography (EMG) respectively. Those data are analyzed and visualized as CG avatar in a VR environment. The proposed system was implemented and two types of motions having different contraction/relaxation timing were compared. In addition, the system was applied to the tennis training.

Key words: Motion Capture System, EMG, Education, Visualization, Sports-Form, Virtual Reality

1. Introduction

Learning the proper physical form is one of the most important factors for effective improvement of sports skills. Many sports define specific sets of physical forms which are traditionally imparted from experienced trainers to novice trainees by mimicking movement of the trainers.

VR-based system which is based on such a model has been already proposed. It displays not only trainers' movements captured previously but also real-time movements of trainees simultaneously. "Just Follow Me" developed by Ungyeon[1] and "MoShAS" developed by Manabe[2] are examples of VR-based motion training system. In these systems, trainees train motions by following trainers' motions. In addition, they are studying the method to provide instruction in other modality than visual, e.g. tactile sense (Ungyeon[3]). These systems are developed for the purpose of education, and Youngblut[4] has reported that the VR-based education supporting is useful.

In the case of sports, non-visible activities, for example how to use muscles or when to breathe, are important as well as visible ones. On the one hand, rehabilitation study reports that the visualization of muscular intensity is effective for training (Duponet[5]). However, since these systems provide only information related to appearance, such as angles of individual joint, speed and directions of body parts, it is difficult to guess invisible status like timing or intensity of muscles.

To address the issue, we propose a learning environment for sport-forms with visualization of biophysical information. The proposed system provides information on intensity of particular muscle which is derived from EMG measurement in addition to captured motion data, simultaneously.

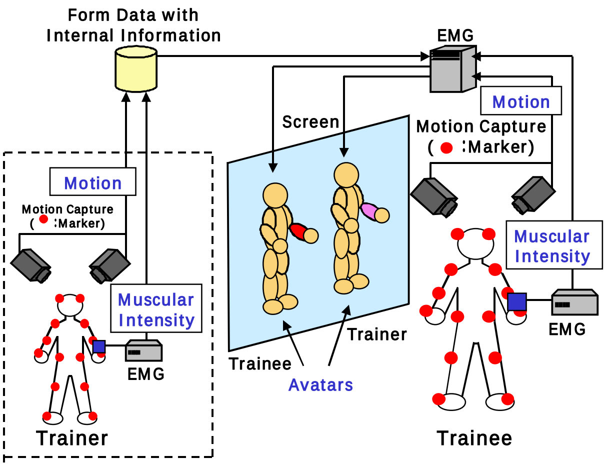


Figure 1: Overview of the system.

2. Proposed System

Figure 1 shows overview of the system. The system can be split into two sides: the trainer and trainee side. On both sides, the system records motion and myoelectric signal of the user from particular muscle simultaneously. The motion capturing system and the multichannel EMG are used for recording motion and EMG respectively. On trainer side, the EMG data is analyzed and indexed by muscular intensity. Then the motion data is reconstructed into an animated CG avatar with visual effect according to the index. On trainee side, motion and EMG are recorded, analyzed as same as trainer's side and displayed in real-time with the trainer's avatar. Therefore, the trainee can learn both the trainer's movement and muscular intensity by mimicking it and comparing difference with his own avatar.

2.1 EMG Analysis

To provide the friendly information on muscular activity, a custom index for muscular intensity is designed. Firstly, the raw EMG signal is rectified and integrated to derive transition of muscular activity. Its result is then classified into ten intensity degrees. Logarithmic range is employed because it distributes intensity degrees balanced than linear thresholds. To distinguish the timing of when to relax or contract muscle, "Meri (relaxation)" and "Hari (contraction)" is defined at rapid decrease or increase of the intensity degree.

2.2 Visualization

Using the captured motion and the derived intensity degree, an animated CG avatar is drawn in VR space. The intensity degree is visualized as color of corresponding body parts. Timing indicator is also displayed on the screen to notify when to contract or relax muscle of individual body part.

3 Results

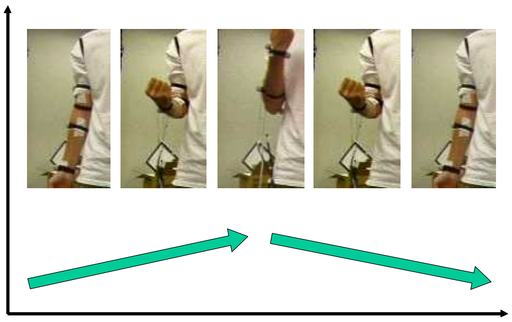
A prototype system was implemented using marker-based motion capture system (Vicon512, Vicon Motion Systems Ltd., U.K) and EMG (MT-11, NEC Medical Systems Corp., Japan). To examine processing/ visualization techniques suitable for instruction of muscular timing and intensity, two types of actions are compared. In addition, tennis training was performed using the system.

3.1 Two Types of Actions

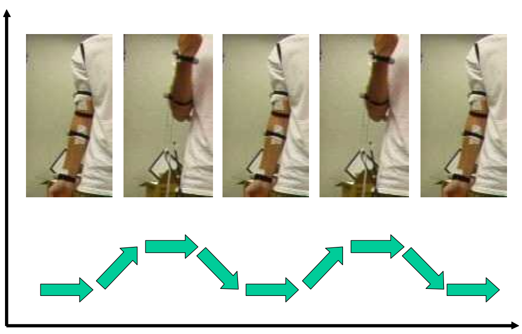
Two motions with different contraction timings were compared (Figure 2). Details of those motions are described below:

• **Motion A:** The arm is bent and stretched at intervals of 1 seconds. The intensity degree is gradually increased and decreased while bending arm for every second (Figure 2(a)).

• **Motion B:** The arm is bent and stretched momentarily at intervals of 2 seconds. While in bending, the intensity degree is momentarily increased and decreased (Figure 2(b)).



(a) Motion A



(b) Motion B

Figure 2: Two type motions

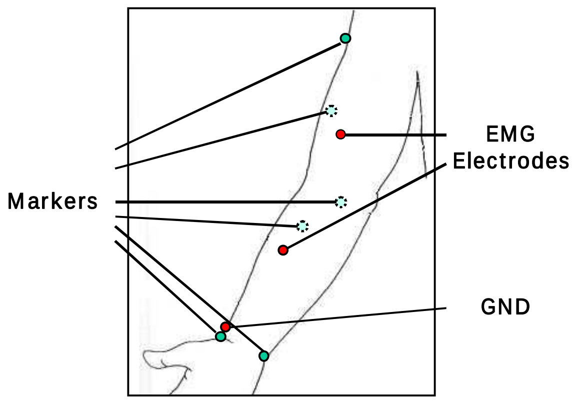
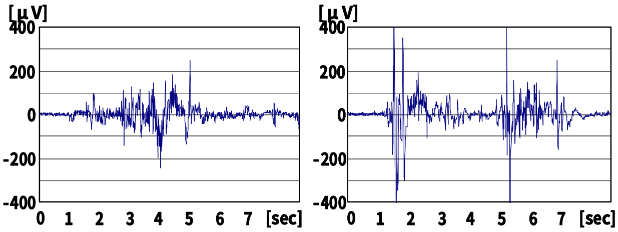


Figure 3: EMG electrodes and markers

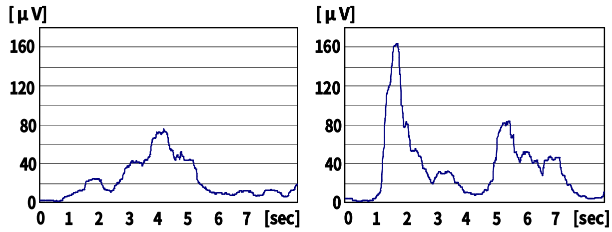
3.1.1 Form and EMG recording

Right arm's movement with straining change was measured using motion capture system and EMG. As shown in Figure 3, for motion, 3-dimensional position of two parts (upper arm, front arm) using 6 markers were recorded in 120 frames/sec. For myoelectric signal, EMG at two positions (biceps brachii, extensor digitorum) were recorded in 120 samples/sec.



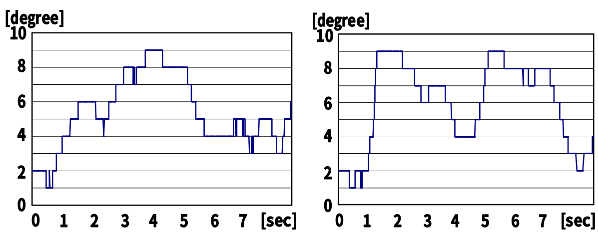
(a) Motion A (b) Motion B

Figure 4: Raw EMG data



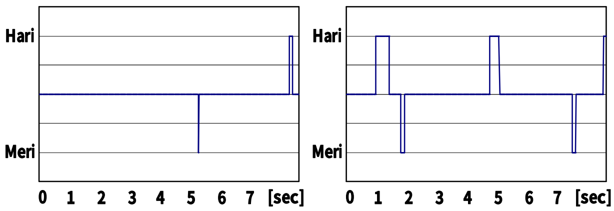
(a) Motion A (b) Motion B

Figure 5: Rectified and smoothed EMG data



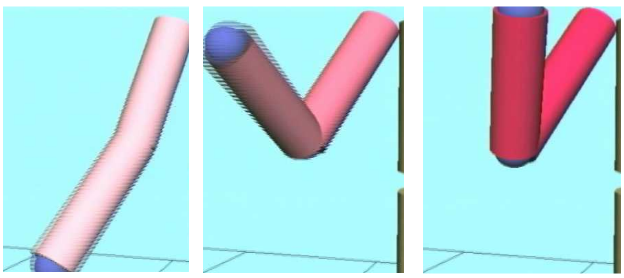
(a) Motion A (b) Motion B

Figure 6: Classification to intensity degree



(a) Motion A (b) Motion B

Figure 7: "Meri" and "Hari"



(a) low (b) medium (c) high

Figure 8: Visualization of muscular intensity

3.1.2 Visualization of intensity degree

Raw EMG data are shown in Figure 4. Spikes occur at forcing actions for both motions. Figure 5 shows the rectified and smoothed results. Spikes are removed, and the transition of muscular intensity is derived. Classification results using 10 levels based on Log(1.5^n μV) are shown in Figure 6. While the transition of intensity degree in motion A (Figure 6a) is gradually, rapid increase/decrease is observed in motion B (Figure 6b) Thus "Meri" and "Hari" is determined as shown in Figure 7. Finally, a movie of CG avatar, with colored arm parts based on intensity index, was drawn in Figure 8.

3.2 Tennis Training

The system was deployed for tennis training. Forehand/ backhand stroke by experienced tennis player was previously recorded using the system. For both case, the motion was performed repeatedly during one minute. Using this training data, trainee performed five sets of training session (repeat 5 times of 1 minute training). Animated CG avatars of both trainer and trainee are projected on a screen, and trainee was instructed to follow the motion and muscular intensity change, caring difference between CG avatars.

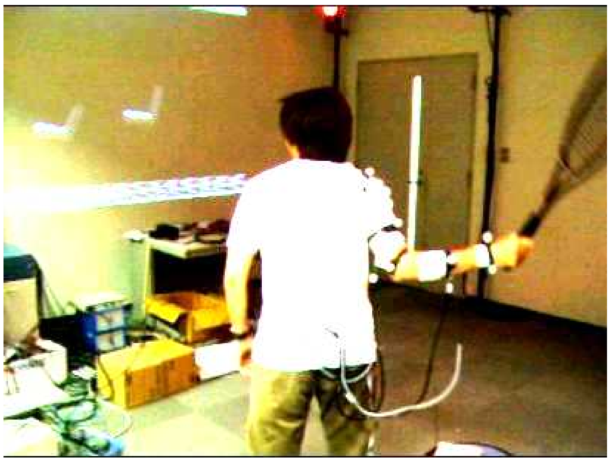


Figure 9: Training the tennis form
(Avatar Left: Trainee, Right: Trainer)

4. Discussion

The muscular intensity is extracted successfully by rectification and smoothing of EMG data. Using logarithmic ranged classification, resulting intensity degree reflects both gradually and rapidly transition, and "Meri" and "Hari" is correctly determined. As the trainee repeated training session, he became to grasp trainer's movement, and able to follow the motion of trainer's CG avatar better. However, trainee was too concentrating on appearance-form to care about the change of muscular intensity very much. Also the arrangement of screen limited direction of trainee's head, made training difficult. Those problems should be resolved in future development, for example by adding visual effects (particles, etc.) or providing functionality that trainee can configure viewpoint for trainer's avatar during the training.

5. Conclusion

We proposed a VR-based environment for sport-form learning. For visualization of muscular activity, log-range classified level for EMG signal was introduced. The prototyped system was developed and two motions having different contraction timing were compared. In addition, the system applied to tennis form training. As a future work, Improvement of visualization processing will be considered, and method to evaluate learning effect will be introduced.

References

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