A PROTOTYPE OF TECHNIQUE TRAINING SYSTEM FOR HUMAN MOTION (SWING)

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Abstract. *We constructed a prototype of technique training system for the human swing motion in the present paper. The swing motion of golf is captured by two highspeed video cameras, which is capable of taking pictures every 1 millisecond at the resolution of 512x512 pixels. Images taken by two cameras were synchronized and the data points on the human body were collected in 3D. The 3D swing motion was dynamically analyzed and put into as initial values to an optimizing calculation. By comparing the actual and the optimized motions, we diagnosed the efficiency of the subject's swing technique. We showed the validity of our system, and were able to advise how the subjects can improve their swing motion.*

1. Introduction

The optimization simulation of baseball pitches and baseball batters [1, 2, 3] revealed the mechanism hidden in the human motion. The highly efficient mechanism of acceleration of the forearm or the bat, which is called the gyro effect, is one of the most significant findings. This calculation of optimization should also be useful when searching for the better technique to manipulate the human parts. We often would like to know how to improve our skills, but it is not so easy. First of all, we usually cannot see ourselves while moving our body segments. Even if we photograph our motion using some video cameras, watch it by ourselves, we cannot easily find whether there is any better technique to realize the essentially same motion or not. In order to match such a need, the optimization method will be a powerful tool. We anticipate faster improvement of our technical skills if we optimize our original motion by numerical simulations.

We have, in our laboratory, two high-speed video cameras, which was originally introduced for the purpose of examining accuracy of hydrodynamical simulations such as flow around a baseball. We attempt to construct a technique training system with these tools, analyzing human motion. We have chosen the motion of swing for the first step because it is not so complicated and is complicated enough to evaluate the validity of the new system when applying to 3D human motion. Among other things, the golf swing requires not only power but also accuracy or some kind of technique; Tiger Woods is not a macho golf player but drives the ball to an amazingly distant place. We considered the golf swing is the suitable human motion for the first application of the system.

2. Description of the Training System for Swing Techniques

The two high-speed video cameras are called “Phantom” which was manufactured by Vision Research Inc. (USA) [4]. The resolution is 512x512 pixels and the maximum frame rate at this resolution is 1000 frames per seconds. Synchronization between two cameras when taking images is possible through TTL signals on a coaxial cable or IEEE1394 network connection (Fig. 1).

We took a picture of a pipe frame (Fig. 2) to calibrate the image's scaling. The distances of cameras from the subject can be obtained from the image of this frame. In order to minimize errors in the measurement, the axes of sight of the two cameras were set up along the respective direction of frame sides (see aligned frames in Fig. 2). This pipe frame is disintegrable and the set of cameras is not so heavy, so that we can carry to any desirable shooting places and take motion images.

The motion pictures taken for this time are displayed in Figure 3. The positions of the hand grip (HG) and those of the clubhead (CH) were collected from the pixel images. This procedure is not carried out automatically at present but in the future we will attempt to use a feature tracking method (see, e.g., [5, 6]). Figure 4 shows the captured data points. As the first step, we adopted a three-segment model that consists of rotation around the body trunk, rotation around arms, and the angle between the club and the arms (or cocking of wrist), which is depicted in Figure 5. The center (C) of the trunk rotation was estimated by finding the equidistant points from every point for the grip and by checking the normality of swing planes that consists of the central point and points for the grip. The property of equidistance of the central point was turned out to be surprisingly good. After these procedures, the angle data (θ_0, θ_1, θ_2) were calculated by performing a vector analysis.

Figure 1: Phantom high-speed video camera

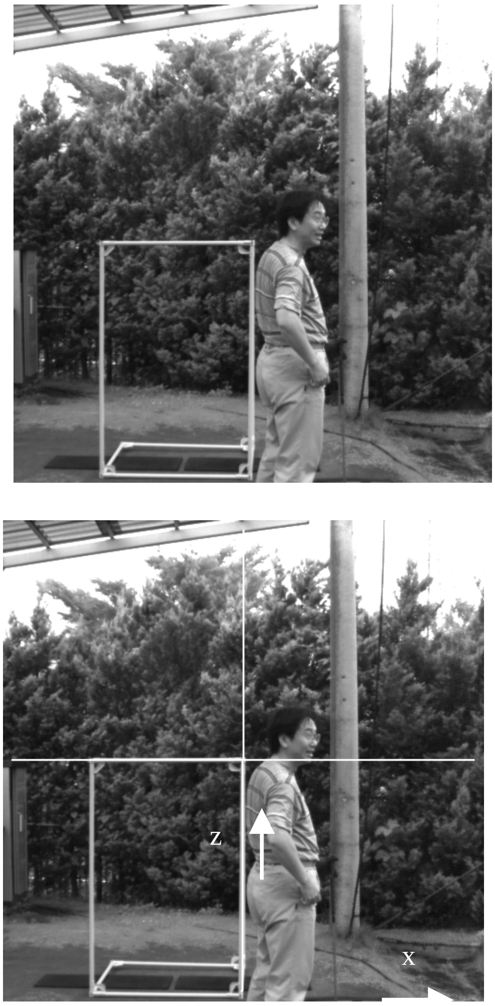
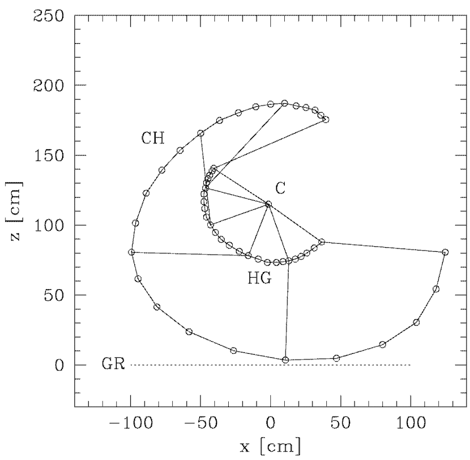


Figure 2a: Pipe frame for the scale calibration (y-axis is along the line of sight)

Figure 2b: Pipe frame for the scale calibration (x-axis is along the line of sight)

Figure 3a: Motion pictures of a swing taken by the first camera

Figure 3b: Motion pictures of a swing taken by the second camera



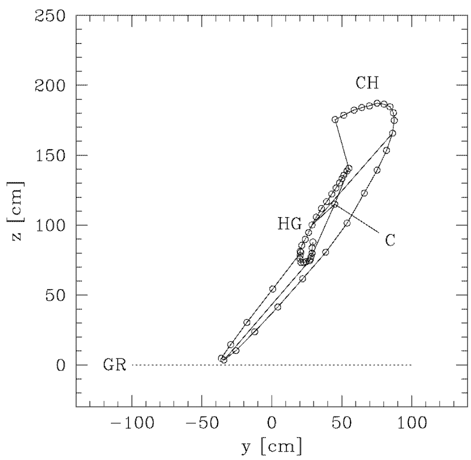


Figure 4a: Captured motion in 3D (x-y plane)

Figure 4b: Captured motion in 3D (y-z plane)

3. Simulation of Optimization and Motion Analysis

Our mathematical model for the golf swing consists of three segments: a body trunk, an upper limb, and a golf club. There are three degrees of freedom (see [1] for details). We collected the coordinate information of data points for the grip and the clubhead. The information of the rigid rotation of the club was not used since the degree of freedom is reduced to the minimal.

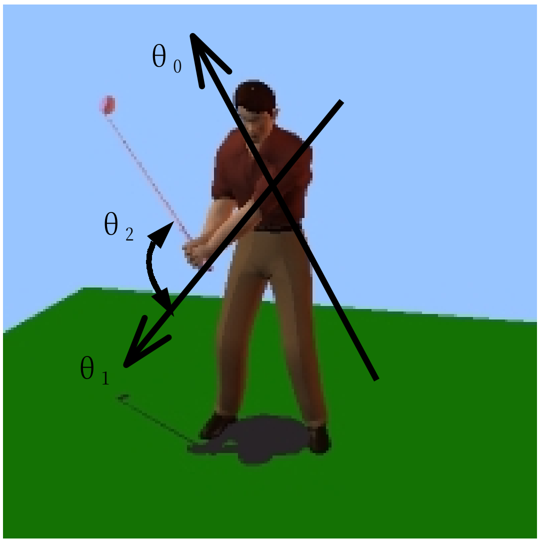


Figure 5: Mathematical model for the swing motion analysis (3 degrees of freedom)

The measured swing motion was put as the initial values into the calculation of optimization. The evaluation function consists of minimizing the total squared torque and the total squared derivatives of torque of the first and second order, smoothing the motion of the club, and giving a penalty on the maximum values of the clubhead speed and the torque around the wrist as well as a penalty on the movability of every joint. The required club head speed was set to 37.0 m/s, which is close to the observed value in the measurement. The actual human swing motion was compared with the optimized motion. The resulting optimized motion (angle data), as well as the actual swing, is shown in Figure 6. Although we could not spot any problems in the captured motion at the first sight, a calculation of optimization was able to tell us where they exist and suggested how to correct it to improve the technique further.

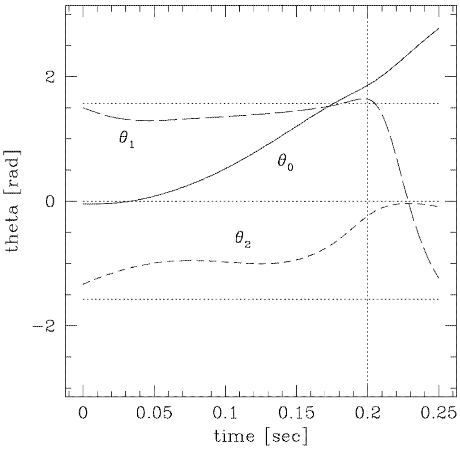


Figure 6a: Optimized swing motion

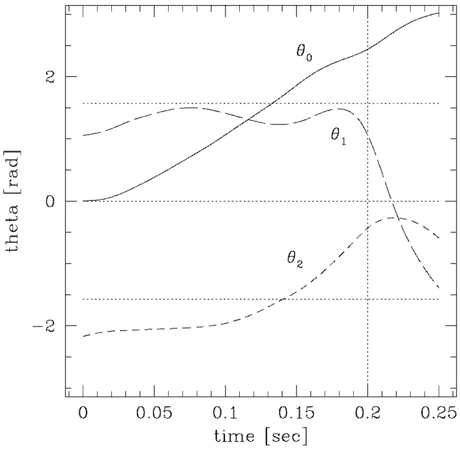


Figure 6b: Captured actual swing (the initial condition for optimization)

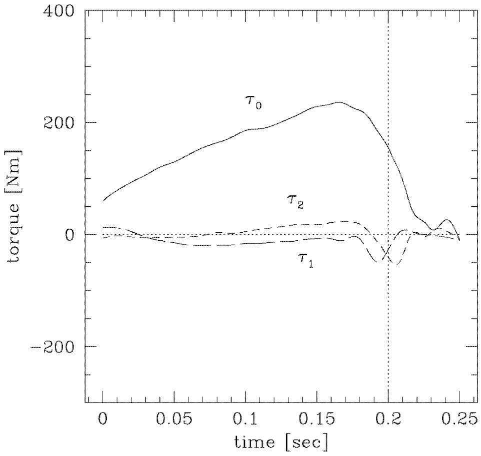


Figure 7a: Torque of the optimized swing motion (τ_0, τ_1, τ_2) around (θ_0, θ_1, θ_2)

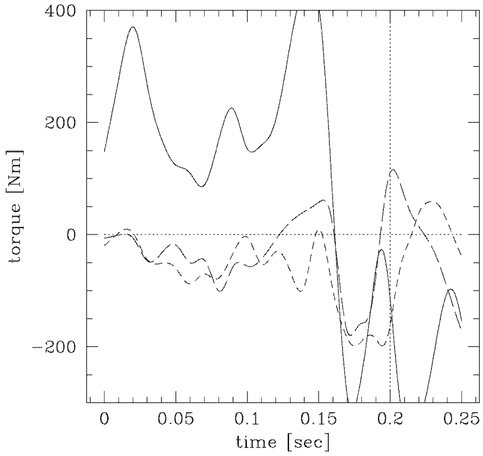


Figure 7b: Inverse dynamical analysis of actual swing; torque (τ_0, τ_1, τ_2) is shown as in Figure 7a

4. Diagnostics of Technique

In Figure 7, we can clearly find much reduced absolute values for the various kinds of torque. We were able to find the more efficient swing motion to realize the same clubhead speed. It should be noted that the oscillation in the profile of the actual motion in a short time scale is due to inaccuracy of the measurement. We should only take into account the overall tendency when observing the measured one.

The subject in this experiment is a good golf player, who belongs to the golf club of RIKEN and makes excellent scores when playing at courses. His overall swing motion bears basic features of his best optimal motion. However, he tends to decelerate the turning of his body just before the ball impact. This deceleration seems to be done to compensate the over-acceleration of his body trunk during the downswing. The optimized solution shows that he had better stop only accelerating at that moment and quit the deceleration. The tip for the better swing motion seems to be the realization of a one-peaked, smooth exertion of the torque around the body trunk. He also tends to turn his trunk too much, compared with the optimized motion. (The origin of theta1 can be offset, in principle, to any value if the effect of gravity is omitted because its effect is small.) Although the timing of turning his arms and hands is not so bad, the continuously exerted torques around hands and arms (τ_2 as well as τ_1 in Figure 7b) made his swing less efficient. He also has a habit of placing the club shaft close to his neck at the top of swing, making the value of θ_1 smaller. This requires extra exertion of torque around the trunk at that instant; this seems to be the cause of the two peaked profile and less efficient release of the wrist cocking. We found, after optimizing, the more efficient motion, in which the torque around hands can be much less than the original one. If he masters the better technique for his efficient, smooth body turn and suppresses the force at hands at the early phase of the downswing, he can swing the golf club with much less torques around hands and arms at the ball impact. This will presumably contributes the accuracy of his swing, endurance of his performance, and consequently, his better scores at golf courses.

5. Discussion

We showed here that the calculation of optimization is useful for the improvement of the human swing technique. We found more efficient motion than an actual swing in order to achieve the same clubhead speed at the impact against a ball. By comparing the optimized and the real swing motion, we were able to give various advices for the better technique.

The simulated model in the present paper is simple: elastic effects of the golf club and translation movement of the body are omitted; two arms are represented by only one rotational angle one degree of freedom is suppressed at the grip; further analysis is still necessary. In the evaluation function, at present, there is no term that describes the accuracy of hitting a ball, only efficiency is taken into account here; feasibility of performing the optimal motion is another problem. In the future, we will change and improve the evaluation function that can also fit the performer's individual needs. We aim to propose an injury-proof training program, in which motion beyond the trainee's power is avoided and the efficient way of practicing to the optimal motion is clearly shown. We hope to contribute to people's good health by having many ordinary persons enjoy various sports by learning nice techniques efficiently.

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