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Simulation model of underhand throw for cybernetic training

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Abstract

Sports training systems are widely used to improve the overall performance of individuals engaged in various activities. Here, we propose the use of optimized muscle activation signals, hereinafter called OPTIMAS, as a tool for improving the overall sport performance of engaged subjects. The system consists of a series of steps that begin with the calculated OPTIMAS waveforms based on musculoskeletal model. The OPTIMAS waveforms are subsequently compared to the measured EMG waveforms. A trial and error based feedback approach is then taken to narrow the difference of the waveforms to finally suggest the best performance of the individual subject. The results of the proposed training system show that the method is of great advantage with a gain that leads to a better performance especially in the early stage of the training term.

Keyword : EMG; genetic algorithm; multi-objective optimization; muscle activation; simulation; cybernetic training

1. Introduction

New skills in sports performance are generally attained through successive engagement of the inexperienced subjects with the aim of imitating the body motion of a skilled athlete. This imitation corresponds to the visually observable information from skilled athletes' posture, body parts position, joint trajectories and motion timings, etc. It is known that having an image to imitate accelerates motor learning, especially in the early stage of practice. However, this visually observable information is restricted to kinematic information. Since kinematics information does not have dynamic information such as muscle tension which drives the body motion, a learner needs to develop an internal model, i.e. a correlation map between body motion and motor command, by trial and error. On the other hand, electromyography (EMG) is a graphical record of a biomedical electric currents signal which directly

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reflects motor commands from the brain to activate muscles contractions. The general aim of EMG is to analyze the function and co-ordination of muscles in different movements and postures of skilled athletes and inexperienced subjects. The method is however, not necessarily effective as an inexperienced athlete would face difficulty in directly imitating skilled athlete's EMG due to the inherent difference in the physical characteristics. Therefore, the differences in physical characteristics limits the use of skilled athlete's EMG signal by inexperienced subjects. In this study, we propose a training system that helps inexperienced athletes to acquire skills through a repeated comparison of their EMG signals measured in real time to that of the signals produced by the optimization calculation using a model considering the physical characteristics of each subject. We call this training system, "cybernetic training" and refers to a feedback based signal produced artificially by optimization of the model calculations.

In this work we studied the underhand throw of softball player to verify the validity of the proposed cybernetic training. At first, we calculate the optimal muscle signal for an underhand throw of a softball based on the subject's physical characteristics. Then, the subject practices to improve his skills by comparing his integrated electromyogram (IEMG) measured in real time with that of the OPTIMAS waveform produced by the optimization calculation. Here, the subject aims to approach the OPTIMAS waveform. The preliminary results showed that the proposed method is effective especially in the early stages of training.

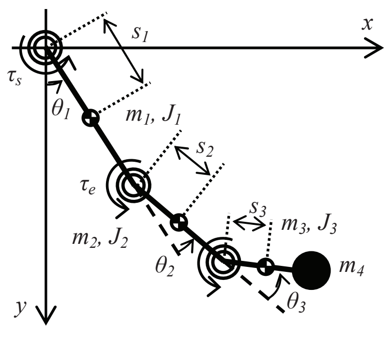
2. Method

2.1. Simulation model

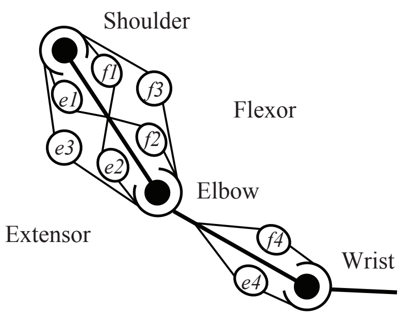
We modeled the upper limb with three joints (shoulder, elbow and wrist) and eight muscle-like actuators. Figure 1a shows a rigid link model in the *xy*-plane. Angles θ_1, θ_2 and θ_3 are the absolute rotating angles of the shoulder joint, the elbow joint and the wrist joint respectively. The masses of the first link, the second link, the third link and the softball are m_1, m_2, m_3, and m_4, and the mass moments of inertia of these rigid links are J_1, J_2 and J_3, respectively. The distances from joint position to center of gravity of these rigid links are s_1, s_2 and s_3, respectively. The system of equations of motion is obtained as:

$$\tau = \boldsymbol{J}\ddot{\theta} + \boldsymbol{H} + \boldsymbol{G} \tag{1}$$

where $\boldsymbol{\tau}$ is the joint torques, $\boldsymbol{J}$ is inertia matrix, $\boldsymbol{H}$ and $\boldsymbol{G}$ are the Carioles and centrifugal terms and gravity term vectors. This equation of motion is solved with a fourth order Runge-Kutta numerical integration.



(a) Coordinate system of the rigid link



(b) Musculoskeletal

Fig. 1. Simulation model of underhand throw of softball