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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (21): 6402-6406, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.6402.6406

Studies on Interactive Evolutionary Computation for Technical Movement Optimization in Competitive Sports

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Abstract: Traditional genetic optimization algorithms only consider the kinematics characteristics of a technical movement, not taking the rationality and natural degree of the movement into account, thus resulting in a not ideal optimization effect. Through analyzing the technical characteristics of the snatch movement, based on the optimal joint torque fitting control model according to micro-motions of snatch, this study uses IEC algorithm to calculate the optimal joint torque and effectively solves the multi-attribute decision making problem of the torque optimization of such unconventional movements. Experimental simulation results show that the method can not only well fitted the joint torque but also meet the requirements of various unconventional indicators of technical movement optimization of snatch.

Key words: IEC Interactive evolutionary computation, snatch, movement optimization

INTRODUCTION

Snatch is a heavy sports competition event with strict technical requirements and high movement ornamental value in competitive sports. Different with the ordinary events and general arbitrary movements of human body, it is not only to meet certain biomechanical constraints but also to comply with the appropriate technical movement rules, such as not raising the barbells from the overhang state, not allowing pause during the raising process, etc. These rules often show the time correlation on the transfer of the joint space. There are other requirements such as the arms cannot stretch uneven or incomplete, the arms bend and stretch when standing up and so on.

There are infinite joint characteristic curves of athlete's snatch process in a continuous space; the aim of the movement optimization is to find a relatively satisfactory moving posture, so that the joint torque value limbs suffered is minimum during raising the barbells and power generation in case the moving trajectory of the end of the joint (barbell) is determined, technical movements within the required time, enabling the limited energy of human muscle play the greatest effect which is an important indicator to examine the merits of technical movement optimization.

For such non-linear, multi-attribute decision making problem, just as Witkin and Kass, (1988) showed in solving of traditional methods are more difficult and the optimization effect of the general genetic optimization algorithms is not ideal b ecause it only considers the kinematics characteristics of the technical movements and does not consider the rationality and natural degree of the movement, The most common is the barbell trajectory which has

been investigated by Chang *et al.* (2001). The interactive genetic algorithm IEC was studied by Gong *et al.* (2004) and Huang *et al.* (2006) and Hu *et al.* (2002) and Jiang *et al.* (2004) and Takagi (2001) and Zhao and Huang (2008) and Zhong *et al.* (2004) and Jin and Branke (2005) which has been proved very useful for such multi-attribute decision making problem of torque optimization of unconventional movement.

MATHEMATICAL DESCRIPTION OF THE SNATCH MOVEMENT

In line with the different characteristics of the whole set of movements, the entire movement course can be divided into the raising barbells, leading knee, generating power, jumping back and supporting as well as jerking five processes, the generating power point is the key of the success of the namely: How to complete the corresponding entire weightlifting movement. Athletes just use this conversion of such external and internal forces to complete the given snatch movement when raising the barbells, to consider this issue from another point of view, the weightlifting movement is a continuous process and human muscle power is limited, how to take advantage of this limited energy is an important indicator to examine the merits of a technical movement.

There are infinite joint characteristic curves of athlete's snatch process in a continuous space; the aim of

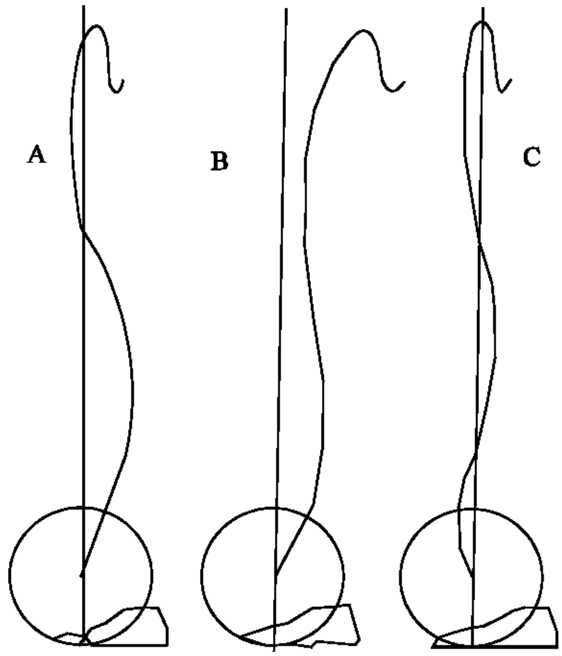

Fig. 1: Three barbell trajectories of snatch proposed by Vorobyev (1978)

the movement optimization is to find a relatively satisfactory moving posture, so that the joint torque value limbs suffered is minimum during raising the barbells and power generation in case the moving trajectory of the end of the joint (barbell) is determined, so under the assumption that the moving posture of the barbells in the processes of raising and generating power is constant, if can determine the moving posture of each joint under which the drag torque of limbs within this time is minimum, we can say that this gesture is relatively optimal. Vorobyev, (1978) suggested three barbell movement patterns for snatch weightlifting roughly depicted in Fig. 1.

Whether the exerting of an athlete in various stages of raising the barbells is the most effective, is determined by the appropriate angle formed by the major joints of the body and the corresponding suitable location of barbells, so only in case the whole course of movement is in accordance with the principles of biomechanics and personal characteristics of an athlete, the athlete can lift more weight of barbells with limited power.

There is a common assumption that has been used by Chang *et al.* (2001), so the five-link model model to analyze lifting tasks was used here.

The model consists of the calf, thigh, torso, upper arm, forearm of five parts, named L_1, L_2…L_5. Furthermore, the joints connecting five parts are ankle, knee, hip, shoulder, elbow, respectively, expressed by O_1…O_5.

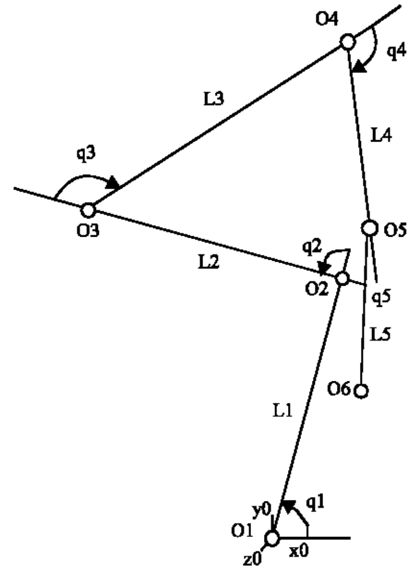

Fig. 2: Biomechanics model in the initial position Equations of motion

Assume a fixed coordinate system (X_0, Y_0, Z_0) at ankle. The motion of the model can be defined by five relative joint coordinate systems:

$$q_I = (X_i,\ X_{i-1})z_i I = 1, \ldots 5\ (z_0 = X_0 \times Y_0 \qquad (1)$$

where, X_i represents the direction of L_i, Z_0 indicates the positive direction of the angle parameter. Introduce the following concepts:

$q = (q_1, \ldots q_5)^T$joint coordinates vector; $q = (q_1, \ldots q_5)^T$, joint velocity vector; $q = (q_1, \ldots, q_5)$ joint acceleration vector.

Where:

$$q_i\ dq_i/dt, q_2\ d^2q_i/\ dt^2 \qquad (2)$$

According to Fig. 2, we define the dimensions and inertia characteristics parameters of the model:

$O_iO_{i+1} = r_i\ x_i$, $I = 1, \ldots 5$; r_i is the length of Li; $O_iG_i = a_i\ x_i$, $I = 1, \ldots 5$, where G_i is the center of gravity of L_i link, α_i is the distance from the proximal joint to the center of gravity, m_i is the mass of link L_i. I_i^z is the moment of inertia of link L_i with respect to the joint axis (O_i, Z_0). The values of these dimension parameters can be calculated by using the model described above according to the weight and height of the weight lifter (Chaffin and Anderson 1991).

The Lagrange equation of motion of the model can be described as:

$$L\ (q, q) = T(q, q)\text{-}U\ (q)$$

where, U is the potential energy, T is the kinetic energy:

$$T(q, q) = 1/2q^{T}M\ (q)\ q \tag{3}$$

M is the mass matrix of kinetic chain, the elements are the complex function of m_i and l_i^z. We can use the Lagrange equation to list the equations of motion:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial q_i}\right)-\frac{\partial L}{\partial q_i}=Q_i^{d}+Q_i^{\partial},i=1...5 \tag{4}$$

The right term of the formula is the torque converted from the generalized force produced by defining the virtual work in the rotational movement. Q_i^{α} represents the actual torque of $L_{i-1}$to L_i relative to O_i point joint suffered. Q_i^{d} is the dissipative torque of the joint. Due to Q_i^{d} is very small compared to Q_i^{d}, so we'll ignore it.

CONSTRAINT CONDITION

Initial and final conditions specify the conditions of start and end positions of the model in the second pulling stage. The starting stage can be expressed with a formula as:

Equation:

$$\begin{aligned} t = 0\ q_i(t) &= q_i^{\text{initial}}, i = 1, \dots, 5\ a \\ V(O_6)\bullet X_0(t) &= 0\ b \\ V(O_6)\bullet Y_0(t) &= 0\ c \end{aligned} \tag{5}$$

$V(O_6)$ is the speed of the barbell at O_6 point as shown in Fig. 2. Equation (5a) defines the positions of each link, namely the position of the center of mass of the barbell. 5b and 5c indicate there is no initial speed in the horizontal and vertical directions at the initial stage.

The description equation of the ending stage:

$$\begin{aligned} O_1O_6\bullet Y_0(t) &= H\ a \\ t = t_{\text{final}}\ V(O_6)\bullet X_0(t) &= V_{xd}\ b \\ V(O_6)\bullet Y_0(t) &= V_{yd}\ c \end{aligned} \tag{6}$$

The first formula (6a) is the vertical position of the barbell at the end of the second pulling stage, 6b and 6c shows the speed in the horizontal and vertical directions of the barbell.

The time between the points of two stages is set to a constant closer to true value.

Design of evaluation function: As previously stated, to obtain the best movement according to the specific criteria, although have a lot of optimization criteria for selection but reducing all joint torques and total power consumption are two criteria of applying optimization selection. To adopt above standards, to unify the actions on all the joints, divide the torque value of each joint or the work generated by its possible maximum power generated. The joint torque often is referred to as muscle function. Therefore, the evaluation function based on the muscle function can be written as:

$$J=\int_{ti}^{ti}\left(\frac{Q_i^{a}}{Q_i^{\max(t)}}\right)^2 dt \tag{7}$$

The function based on power consumption can be written as:

$$J=\sum{}_{i}^{5}=1\int_{ti}^{ti}\left(\frac{Q_i^{a}(t)\,\omega_t}{Q_i^{\max(t)}\,\omega_i^{\max}}2\,dt\right) \tag{8}$$

In the above Equation, Q_i^{α} is the calculated actual joint torque, Q_i^{max} is the maximum value of the actual joint torque, ω_i is the angular velocity of the joint, ω_t is the maximum value of the angular velocity of the joint. Therefore Eq. 7 describes the normalized sum of joint torques; Eq. 8 describes the normalized sum of the work of joints. We can use Eq. 7 and 8 to get the consideration of each solution. For this purpose, Eq. 4 shall be solved to calculate the actual joint torque. The inverse dynamics method can be used to solve the problem. Using Eq. 7-8, to convert the minimizing the exerting of limbs of snatch movement into the typical space-time optimization of the joint space.

DESCRIPTION OF THE INTERACTIVE GENETIC ALGORITHM BASED ON IEC

- Determine the initial value of the joint angle at the beginning and ending point and select the intermediate node, define the moving time of each trajectory segment
- Define the fitness function
- Determine the operation strategies and population size N, crossover probability P_c, mutation probability P_m. These three parameters are the main parameters of GA algorithm, if N is too large, P_c is too small or P_m is too large, it is difficult to converge; otherwise premature convergence will occurs, causing prematurity phenomenon
- Grade the initial population with the reverse dynamic method
- Decode the string in the population, plan each trajectory using recursive trajectory planning method
- Calculate the fitness of each string
- Carry out statistics on the fitness of population, introduce the user fitness evaluation and retain the best string
- Apply the roulette wheel selection to select the operation

Table 1: All optimization parameters of the simulation

Item number	Description	Value
1	Each joint angle at initial time (¡£)	(80, 85, -155, -110)
2	Upper limit of joint motion angle(¡£)	(95,90,0, -90,0)
3	Lower limit of joint motion angle(¡£)	(75,0, -155, -170,0)
4	Duration and time interval (seconds)	(0.7,0.01)
5	Maximum allowable torque of joint (Nm)	(250,350,500,150,

Table 2: Results comparison

Data	Success 1	Success 2	Success 3	Success 4	Success 5	Failure 1	Failure 2	Failure 3	Failure 4	Failure 5
Deviation	31	38	32	28	27	98	120	140	166	152

- Select points to carry out crossover operation according to the random numbers
- Select a point to perform the mutation operation to generate a new generation of groups
- Jump to the fifth step, repeat the process until certain generation numbers are completed
- Obtain the optimal power generation moving time H(t) and optimal acting P(t)

SIMULATION RESULT

In order to verify the effectiveness of the algorithm, to conduct a simulation experiment with MATLAB7.9. The object is an athlete with height 1.8m in Men's 80kg class, he snatch 180 kg and 100 kg barbells, respectively, we select 10 samples, among them 5 successes and 5 failures and convert the optimized values and experimental values.

RESULT COMPARISON

Perform a control experiment using the measured snatch data, the scheme is as follows:

- Select 10 test samples, among them 5 successes and 5 failures and convert the optimized values and experimental values
- Calculate the deviations of 5 successful actions and 5 failure actions from the optimal value, respectively Table 1
- Compares the results
- The results are shown in Table 2, it can be seen clearly that the successful actions are closer to the optimal value than the failure actions which further verifies the optimization model we established is reasonable and effective

CONCLUSION

Through analyzing the characteristics of the snatch movement, aiming at the micro-motions of snatch, this study establishes an optimal joint torque fitting control model and uses IEC algorithm to calculate the optimal joint torque, the error indicates that this model can well fit joint torque; Through the simplified model of snatch's lifting barbells, focuses on the movement optimization based on minimum joint torque, the experimental results further validate the rationality and effectiveness of the optimization model.

The optimization analysis method utilized in this study can be used as a reference in the technical diagnostic for snatch but because the modeling and motion simulation of human motion is a very complex topic, is still faced with many difficult and complex task which is the effort of the next stage of this study.

ACKNOWLEDGMENTS

The authors would like to thank for the support by Education Bureau of Guangzhou under Grant No. 2012A162.

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