Optimizing Simulation for Long Distance Throw in Baseball According to an Order of Plural Objectives in Practice

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No.1

Motivation and Purpose

Situation

When a person learns a motion with plural objectives, the person will make a practice so that each objective is satisfied one by one according to an adequate order because it is difficult to satisfy all objectives at the same time.

(1) It may happen that the satisfied objective is broken when the objective is changed to another.
(2) It may happen that the consequent motions are different from each other with depending on the order for the practice to accomplish an objective.

Purpose

(1) Executing the simulation experiment applied an optimizing calculation for a motion of long distance throw in baseball by way of example, when the importance among plural objectives is changed in the improving process according to an order.

(2) Investigating the consequent motion from the simulation experiment.

(3) Investigating the converging process to the consequent motion.

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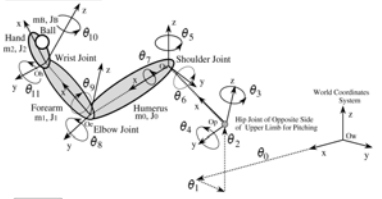
Mathematical Model

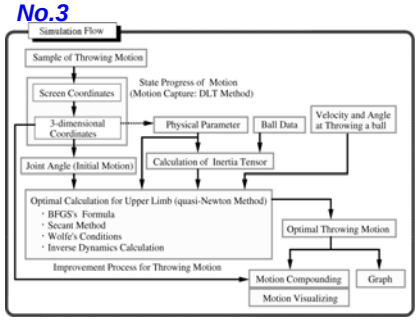


Features

(1) The model has 4 segments, a humerus, a forearm, a hand, and a ball
(2) The model has 12 degrees of freedom, 5 degrees of freedom for controlling a trajectory of a shoulder joint and 7 degrees of freedom for controlling an upper arm.
(3) D-H (Denavit-Hartenberg) representation is applied to the local coordinate system

No.3

Simulation Flow



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Objective Function

$$E\ (\Theta(t)) = W_{V0}\int\ (\tau_3^2+\tau_4^2)\ dt + W_{V1}\int\ (\tau_5^2+\tau_6^2+\tau_7^2)\ dt$$
$$+ W_{V2}\int\ (\tau_8^2+\tau_9^2)\ dt + W_{V3}\int\ (\tau_{10}^2+\tau_{11}^2)\ dt$$
$$+ W_0\ \text{(Penalty for Joint Movability)}$$
$$+ W_1\ \text{(Penalty for the Range and the Smoothness of Shoulder Trajectory)}$$
$$+ W_2\ \text{(Penalty for Joint Torque)}$$
$$+ W_3\int\left[(d\tau_3/dt)^2+(d\tau_4/dt)^2+\cdots+(d\tau_{11}/dt)^2\right]dt$$
$$+ W_4\int\left[(d^2\tau_3/dt^2)^2+(d^2\tau_4/dt^2)^2+\cdots+(d^2\tau_{11}/dt^2)^2\right]dt$$
$$+ W_5\ \text{(Penalty for Ball Velocity)}$$
$$+ W_6\int\ (v_x^2+v_e^2+v_w^2+v_h^2)\ dt$$
$$+ W_7\int\left[(dv_x/dt)^2+(dv_e/dt)^2+(dv_w/dt)^2+(dv_h/dt)^2\right]dt$$
$$+ W_8\int\left[(d^2v_x/dt^2)^2+(d^2v_e/dt^2)^2+(d^2v_w/dt^2)^2+(d^2v_h/dt^2)^2\right]dt$$
$$+ W_9\ \text{(Penalty for Angle at Throwing)}$$

where $\Theta(t)=(\theta_3(t), \theta_4(t), \cdots, \theta_{11}(t))$

No.5

Weight Coefficients

We developed the optimizing method with changing the weight coefficients dynamically in our previous works.

A weight coefficient corresponds to the importance of an objective in the objective function with plural objectives.

Utilizing the dynamic change of the weight coefficients for the simulation experiments.

Determining Weight Coefficients and Optimizing process

(1) calculating the value V_{S0} of the 2nd term when W_{S1}=1 for an initial motion.
(2) W_S are determined by the way such that the ratio of V_{S0} to each value of the 1st term, the third term, and the fourth term is "*1: 1: 1*".
(3) the total value V_0 from the 1st term to the 4th term is calculated.
(4) the weight coefficients W_i are determined by the way such that the ratio of V_0 to each value from the 5th term to the 14th term is "*1: 1: 1: a: b: c: d: e: f: g*".
(6) when the optimizing process is converged, the succeeding optimizing process is executed after the initial motion is changed to the preceding converged throwing motion with renewing weight coefficients,
(7) these optimizing processes are repeated until the improvement for the value of the objective function does not happen.

No.6

Simulation Condition for the Order of Importance

· We classify objectives in the objective function (5) to the condition of the angle at release, the condition of the velocity at release, and the condition of the smooth, and those can be controlled by the values from "*a*" to "*g*".
· According to the classification, we determined following 3 types of weight coefficients from the ratio.

for the condition of angle
Weight Type (1) : a=0.1, b=0.1, c=0.1, d=0.1, e=0.05, f=0.025, and *g=5.0.*
for the condition of velocity
Weight Type (2): a=0.1, b=0.1, c=5.0, d=5.0, e=2.5, f=1.25, and *g=0.1.*
for the condition of smooth
Weight Type (3) : a=5.0, b=2.5, c=0.1, d=0.1, e=0.05, f=0.025, and *g=0.1.*

The condition of the six kinds of orders for the optimization

Execution Cycle	1	2	3
Condition A	*Weight Type (1)*	*Weight Type (2)*	*Weight Type (3)*
Condition B	*Weight Type (1)*	*Weight Type (3)*	*Weight Type (2)*
Condition C	*Weight Type (2)*	*Weight Type (1)*	*Weight Type (3)*
Condition D	*Weight Type (2)*	*Weight Type (3)*	*Weight Type (1)*
Condition E	*Weight Type (3)*	*Weight Type (1)*	*Weight Type (2)*
Condition F	*Weight Type (3)*	*Weight Type (2)*	*Weight Type (1)*

No.7

Simulation Condition

Physical Data and Ball Data

	Mass (kg)	Inertia Tensor I_{xx} (m²kg)	Inertia Tensor I_{YY} (m²kg)	Inertia Tensor I_{ZZ} (m²kg)	Inertia Tensor I_{XY} (m²kg)	Inertia Tensor I_{ZX} (m²kg)	Inertia Tensor I_{YZ} (m²kg)
Humerus	1.934663	2.2021262 ×10⁻²	1.21482978 ×10⁻²	1.24127924 ×10⁻²	1.81309 ×10⁻⁵	-6.0618 ×10⁻⁶	-4.24122 ×10⁻⁵
Forearm	1.127990	8.025930 ×10⁻⁴	5.7933046 ×10⁻³	5.9546091 ×10⁻³	8.304 ×10⁻⁷	6.455 ×10⁻⁷	9.38436 ×10⁻⁵
Hand	0.3454527	2.081984 ×10⁻⁴	4.655006 ×10⁻⁴	5.049077 ×10⁻⁴	-1.5749 ×10⁻⁶	-2.3634 ×10⁻⁶	-1.19011 ×10⁻⁵
Ball	0.1418	7.4739 ×10⁻⁵	7.4739 ×10⁻⁵	7.4739 ×10⁻⁵	0.0	0.0	0.0

Threshold Value

Wrist Joint: 10.0 Nm	Elbow Joint: 50.0 Nm
Ball Velocity: 33.33 m/sec	Angle at release: 40-45 degree

Simulation Time: 0.5999sec (From Take-back Phase to Follow-through phase)
Calculation Step Time: 0.0020 sec (300 steps)
Ball Relrease was assumed to occur between 0.3400 and 0.4199 sec

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Results and Discusion

Maximum Velocities and Angles

	Condition A	Condition B	Condition C	Condition D	Condition E	Condition F
Shoulder (m/s)	6.63 (0.302)	6.52 (0.298)	6.33 (0.298)	6.92 (0.304)	6.77 (0.298)	6.67 (0.298)
Elbow (m/s)	9.65 (0.370)	12.59 (0.322)	8.05 (0.366)	10.54 (0.358)	6.72 (0.370)	10.16 (0.370)
Wrist (m/s)	18.01 (0.394)	19.55 (0.394)	15.59 (0.382)	18.87 (0.378)	13.38 (0.416)	18.40 (0.390)
Hand (m/s)	23.95 (0.402)	25.23 (0.400)	19.25 (0.382)	24.34 (0.384)	16.44 (0.400)	25.75 (0.388)
Ball (m/s)	24.90 (0.390)	25.45 (0.382)	23.84 (0.382)	26.88 (0.374)	17.14 (0.408)	27.68 (0.386)
Angle (degree)	40.69	42.43	42.30	40.94	40.79	42.07

· The condition of angle at release was satisfied in all conditions.

· The velocity at ball release was insufficient from the threshold value in all conditions.

Because there were some conditions decreasing the ball velocity in the objective function. The condition of the ball velocity will be satisfied if the conditions decreasing the velocity is removed or the weight coefficient for it is increased large value.

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Conclusion

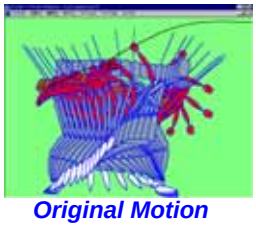
(1) we reported the simulation method by optimizing calculation for a motion of long distance throw in baseball when the importance among plural objectives was changed in the improving process according to an order.

(2) We also mentioned the simulation experiment and its results.

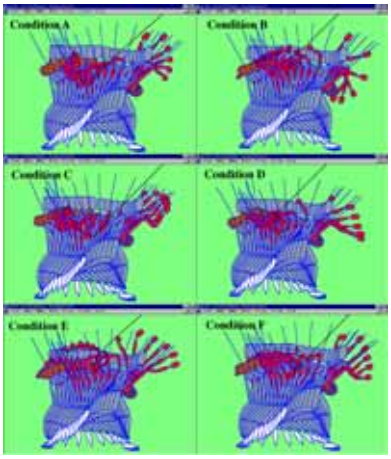
(3) From the consequence, it could be concluded that a throwing motion converged to the different type of a motion by the improving process according to the order of the importance for plural objectives, even if it began from the same initial motion.

(4) The consequent motion was more different from the initial motion as increasing the number of the iteration for improving by the optimization.

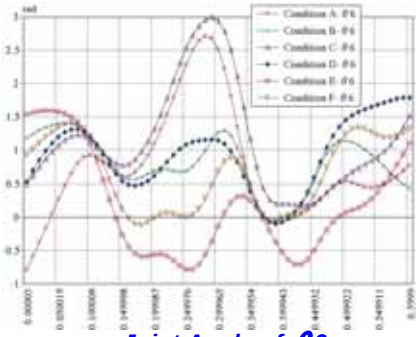
(5) If we can apply the conclusion from the simulation experiment to an actual human, it may be necessary to consider the order of an importance for plural objectives when a person makes a practice. The difference among motions by players may be concerned with not only a differnce of a condition of a body, but also difference of the order of an importance for plural objectives in a practice.



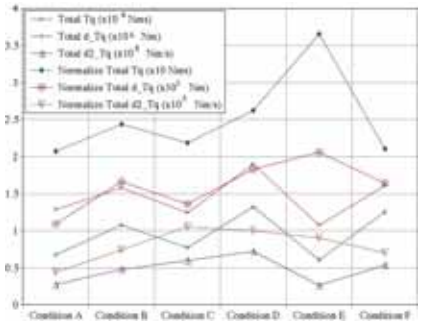
Original Motion



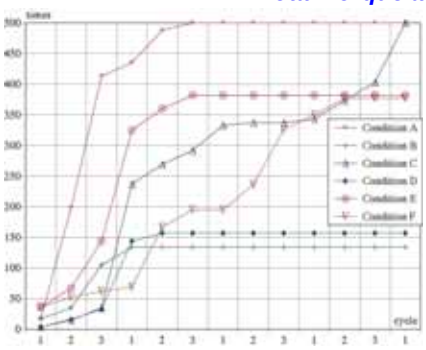
Consequent Motions



Joint Angle of θ6



Total Torque and Torque Derivatives



Converging Process