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*Research article*

## **Application of an improved whale optimization algorithm in time-optimal trajectory planning for manipulators**

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### **Supplementary**

**Table S1.** Symbol meaning table.

Section	Symbol	Meaning
2	$p(x)$	The segmented rational polynomial function of NURBS curve
	$\omega$	The weight factor of the NURBS curve
	$d_i$	The control vertex of the NURBS curve
	$k$	The degree of the NURBS curve
	$N_{i,k}(x)$	The basis function of the NURBS curve
	$x$	The parameter of the NURBS curve
	$h_i$	The other knot values of the NURBS curve
	$p^{(k)}(x)$	The derivative equation of the NURBS curve
	$v$	The angular velocity
	$a$	The angular acceleration
3	$X^*(t)$	The best position of WOA
	$X(t)$	The present position of WOA
	$t$	The present iteration of WOA
	$A$	The adjustment factors of WOA

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Section	Symbol	Meaning
	$C$	The adjustment factors of WOA
	$D_q$	The distance between the whale and the prey
	$S_t$	The current state of the agent
	$action_t$	The current action of the agent
	$r_t$	The current reward of the agent
	$Q(s,a)$	The value function update formula of reinforcement learning
	$\alpha$	The learning rate of reinforcement learning
	$\gamma$	The discount factor of reinforcement learning
4	$f(x_i^t)$	The fitness function value of the $i$ -th individual in the $t$ -th iteration
	$C_t$	The convergence of the algorithm
	$D_t$	The diversity of the algorithm
	$B_t$	The balance of the population in each generation
	$\varepsilon$	The greedy rate of reinforcement learning
	$N$	The population number of all algorithms
	$t_{max}$	The number of iterations

**Figure 2.** Full name of abbreviation.

Abbreviation	Full name
WOA	Whale Optimization Algorithm
RLWOA	The improved WOA proposed in this paper
VNS	Variable Neighborhood Search
PSO	Particle Swarm Optimization
IWOA	The improved WOA proposed in paper [13]
MSWOA	The improved WOA proposed in paper [14]
MWOA	The improved WOA proposed in paper [15]
NURBS	Non-uniform B-spline
RSA	Reptile Search Algorithm
SO	Snake Optimization
DQN	Deep Q-learning Network
DDPG	Deep Q-learning Network
TD-3	Twin Delayed Deep Deterministic Policy Gradient



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