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Improving Whale Optimization Algorithm by Using Logistic Map

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1. Introduction

Swarm intelligence algorithm is optimization algorithm which simulate behavior of creature. Examples are Ant Colony Optimization (ACO), Artificial Bee Colony Algorithm (ABC) and Whale Optimization Algorithm (WOA), etc.

In this study, we propose WOA improved by using Logistic Maps for random coefficients. We compare results of the proposed method and the conventional WOA.

2. Whale Optimization Algorithm

Whale Optimization Algorithm (WOA) is proposed by Mirjalili and Lewis. WOA is nature-inspired meta-heuristic optimization algorithm which mimics the feeding behavior of humpback whales. There are three types of whale feeding behavior: Search for prey, Encircling prey and Bubble-net attacking. The procedure for WOA to search for answer is shown below.

Step 0. Initialize the whales population n and the maximum number of iterations t_{max}.

Step 1. Set the position of the whale $\overrightarrow{X_i}$. i is the number of the whale.

Step 2. Calculate the fitness value f_i and update the best whale position $\overrightarrow{X^*}$.

Step 3. Update $\vec{a}$, $\vec{r_1}$, $\vec{r_2}$, $\overrightarrow{A}$, $\overrightarrow{C}$, l and p. $\vec{a}$ is linearly decreased from 2 to 0 over the course of iteration. $\vec{r_1}$, $\vec{r_2}$ and p are random coefficient in [0,1]. l is random coefficient in [-1,1]. $\overrightarrow{A}$ and $\overrightarrow{C}$ is determined by Eq. (1) and Eq. (2).

$$\overrightarrow{A} = 2\vec{a}.\vec{r_1} - \vec{a} \tag{1}$$

$$\overrightarrow{C} = 2\vec{r_2}. \tag{2}$$

Step 4. Update the position of the whale by Eq. (3), Eq. (4) and Eq. (5). Equations are selected by $|\overrightarrow{A}|$ and p.

Step 5. Repeat steps 2 to 4 and output the solution.

$$\begin{cases} \overrightarrow{D} = \overrightarrow{C}.\overrightarrow{X^*}(t) - \overrightarrow{X}(t)| \\ \overrightarrow{X^*}(t+1) = \overrightarrow{X}(t) - \overrightarrow{A}.\overrightarrow{D} \end{cases} \quad (if\ |\overrightarrow{A}| \leq 1,\ p \leq 0.5) \tag{3}$$

$$\begin{cases} \overrightarrow{D'} = |\overrightarrow{X^*}(t) - \overrightarrow{X}(t)| \\ \overrightarrow{X}(t+1) = \overrightarrow{D'} e^l \cos(2\pi l) + \overrightarrow{X^*}(\mathrm{t}) \end{cases} \quad (if\ |\overrightarrow{A}| \leq 1,\ p > 0.5) \tag{4}$$

$$\begin{cases} \overrightarrow{D_{rand}} = |\overrightarrow{X_{rand}} - \overrightarrow{X}(t)| \\ \overrightarrow{X}(t+1) = \overrightarrow{X_{rand}} - \overrightarrow{A}.\overrightarrow{D_{rand}}. \end{cases} \quad (if\ |\overrightarrow{A}| > 1) \tag{5}$$

3. Proposed method

WOA has $\vec{r_1}$, $\vec{r_2}$, and l which are random coefficients. We insert Logistic Map to random coefficients to improve search ability of WOA. Logistic Map shows a chaotic behavior and is formulated by Eq. (6). We set the parameter $\alpha = 4.0$ and the initial value $z(0) = 0.11$.

$$z(t+1) = \alpha z(t)(1 - z(t)). \tag{6}$$

4. Simulation result

We compare the proposed method to WOA with for test functions. Formula, range and the optimal value of each function are shown in Table 1. x is variable in the function. x_i denotes i-dimensional x.

Table 1: Test functions

Name	Formula	Range	Optimal value
f_1	$\max\ \{\lvert x_i\rvert, 1 \leq i \leq 30\}$	[-100,100]	0
f_2	$\sum_{i=1}^{30} [100(x_i + 1 - x_i^2)^2 + (x_i - 1)^2]$	[-100,100]	0
f_3	$\sum_{i=1}^{30} -x_i \sin(\sqrt{\lvert x_i\rvert})$	[-5.12,5.12]	-12569
f_4	$4{x_1}^2 - 2.1{x_1}^4 + \frac{1}{3}{x_1}^6 + x_1x_2 - 4{x_2}^2 + 4{x_2}^4$	[-5,5]	-1.0316

Each numerical experiment runs 20 times. In each test function, we define $t_{max} = 500$, $n = 30$. Average value, minimum value and maximum value are shown in Table 2.

Table 2: Results of WOA and proposed method

name		WOA	proposed method
f_1	ave	$\mathbf{1.144 \times 10^{-9}}$	6.584×10^{-4}
	min	$\mathbf{4.648 \times 10^{-14}}$	3.397×10^{-13}
	max	$\mathbf{5.572 \times 10^{-9}}$	2.961×10^{-3}
f_2	ave	2.702×10^{1}	$\mathbf{1.150 \times 10^{1}}$
	min	2.934×10^{0}	$\mathbf{4.482 \times 10^{-2}}$
	max	2.9714×10^{1}	$\mathbf{2.9708 \times 10^{1}}$
f_3	ave	-1.230×10^{4}	$\mathbf{-1.246 \times 10^{4}}$
	min	$\mathbf{-1.2569 \times 10^{4}}$	$\mathbf{-1.2569 \times 10^{4}}$
	max	-1.027×10^{4}	$\mathbf{-1.171 \times 10^{4}}$
f_4	ave	-1.0307×10^{0}	$\mathbf{-1.0309 \times 10^{0}}$
	min	$\mathbf{-1.0316 \times 10^{0}}$	$\mathbf{-1.0316 \times 10^{0}}$
	max	-1.0281×10^{0}	$\mathbf{-1.0282 \times 10^{0}}$

The proposed method obtains better value in cases of f_2, f_3 and f_4. However, minimum value is same value in f_3 and f_4. WOA obtains better value in f_1.

5. Conclusion

We have proposed WOA with Logistic Map used for random coefficients. We compared WOA and the proposed method in four functions. Simulation results show that proposed method is better than WOA in three functions.

As our future works, We try to improve search performance by using other chaos for random coefficient.