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Whale Optimization Algorithm with Agents Being Chased by Orcas

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1. Introduction

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

In this study, we propose a new WOA considering that whales escape from the orca. We compare results of the proposed method and the conventional WOA.

2. Whale Optimization Algorithm

WOA is nature-inspired meta-heuristic optimization algorithm which simulate the feeding behavior of humpback whales. WOA is characterized by high search performance for unimodal functions. WOA has some parameters. $|\vec{A}|$ is decreased from 2 to 0 over the course of iteration. WOA updates position of agents by Eqs. (1), (2) or (3).

$(if\ |\vec{A}| \le 1,\ p \le 0.5)$

$$\begin{cases} \vec{D} = |\vec{C}.\vec{X^*}(t) - \vec{X}(t)| \\ \vec{X}(t+1) = \vec{X}(t) - \vec{A}.\vec{D}. \end{cases} \tag{1}$$

$(if\ |\vec{A}| \le 1,\ p > 0.5)$

$$\begin{cases} \vec{D'} = |\vec{X^*}(t) - \vec{X}(t)| \\ \vec{X}(t+1) = \vec{D'}e^{bl}\cos(2\pi l) + \vec{X^*}(t). \end{cases} \tag{2}$$

$(if\ |\vec{A}| > 1)$

$$\begin{cases} \overrightarrow{D_{rand}} = |\overrightarrow{X_{rand}} - \vec{X}(t)| \\ \vec{X}(t+1) = \overrightarrow{X_{rand}} - \vec{A}.\overrightarrow{D_{rand}}. \end{cases} \tag{3}$$

Where $|\vec{A}|$ is decreased from 2 to 0 over the course of iteration.

3. Proposed Method

The possibility that WOA finds local solution is high. We propose Whale Optimization Algorithm with Orca(WOAO) to escape from the local solution. In WOAO, when a search agent approaches an Orca agent, it will perform a different search than usual. Orca chases whales the farthest whales from optimal solution. Orca moves according to Eqs. (4) or (5).

$$\begin{cases} \vec{D} = |\vec{C}.\vec{X_w}(t) - \vec{X_e}(t)| \\ \vec{X_e}(t+1) = \vec{X_e}(t) - \vec{A}.\vec{D}. \end{cases} \quad (if\ p \le 0.5) \tag{4}$$

$$\begin{cases} \vec{D'} = |\vec{X^*}(t) - \vec{X_e}(t)| \\ \vec{X_e}(t+1) = \vec{D'}e^{bl}\cos(2\pi l) + \vec{X_w}(t). \end{cases} \quad (if\ p > 0.5) \tag{5}$$

Where $\vec{X_e}$ is position of orca and $\vec{X_w}$ is position of the farthest whales from the optimal solution. Whales escape from orcas under Eq. (6).

$$|\vec{X_e}(t) - \vec{X}(t)| < |\vec{X^*}(t) - \vec{X_w}(t)|/2. \tag{6}$$

When escaping from a orca, the whale move in consideration of its previous movement. The chased whale moves according to Eqs. (7)-(11).

$$w(t) = rand[0.5, 1.5]\exp\left(\frac{t - t_{max}/2}{100}\right)^2. \tag{7}$$

$$\vec{V}(t+1) = w\vec{V}(t) + \vec{X}(t) - \vec{X}(t-1). \tag{8}$$

$(if\ |\vec{A}| \le 1,\ p \le 0.5)$

$$\begin{cases} \vec{D} = |\vec{C}.\vec{X^*}(t) - \vec{X}(t)| \\ \vec{X}(t+1) = w(t)\vec{V}(t) + \vec{X}(t) - \vec{A}.\vec{D}. \end{cases} \tag{9}$$

$(if\ |\vec{A}| \le 1,\ p > 0.5)$

$$\begin{cases} \vec{D'} = |\vec{X^*}(t) - \vec{X}(t)| \\ \vec{X}(t+1) = \vec{w}(t)\vec{V}(t) + \vec{D'}e^{bl}\cos(2\pi l) + \vec{X^*}(t). \end{cases} \tag{10}$$

$(if\ |\vec{A}| > 1)$

$$\begin{cases} \overrightarrow{D_{rand}} = |\overrightarrow{X_{rand}} - \vec{X}(t)| \\ \vec{X}(t+1) = \vec{w}(t)\vec{V}(t) + \overrightarrow{X_{rand}} - \vec{A}.\overrightarrow{D_{rand}}. \end{cases} \tag{11}$$

4. Simulation Results

We compare WOAO to the conventional WOA with benchmark functions. Formula, range and the optimal value of each function are shown in Table 1. The x_i denotes i-dimensional variable in the function.

Table 1: Benchmark functions.

Name	Formula	Range	Optimal value
f_1	$\sum_{i=1}^{n} {x_i}^2$	[-100,100]	0
f_2	$\sum_{i=1}^{n} -x_i \sin(\sqrt{\lvert x_i \rvert})$	[-500,500]	$-418.9829 \times n$

Each numerical experiment runs 100 times. In each test function, we define $t_{max} = 1000$, $n = 30$ and 50. Average values of 100 times are shown in Table 2.

Table 2: Results of WOA and the proposed method.

		WOA	WOAO
f_1	30 dimensions	$\mathbf{7.07 \times 10^{-43}}$	9.59×10^{-31}
	50 dimensions	$\mathbf{8.56 \times 10^{-36}}$	3.86×10^{-27}
f_2	30 dimensions	-6852	$\mathbf{-8884}$
	50 dimensions	-11191	$\mathbf{-13528}$

WOAO obtains better results than the conventional WOA in multimodal function. However WOAO obtains inferior results to the conventional one in unimodal function.

5. Conclusion

We proposed the new WOA considering that whales escape from the orca to escape from the local solution. The search performance of the conventional WOA proposal method is compared by searching the minimum value of the benchmark function. We confirmed that the proposed method obtains better results than the conventional WOA in multimodal functions.