Whale Optimization Algorithm with Natural Enemy

Hidehiro SUGIOKA, Yoko UWATE and Yoshifumi NISHIO
(Tokushima University)

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 natural enemy. 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 linearly decreased from 2 to 0 over the course of iteration. $\overrightarrow{A}$ is determined by Eq. (1).

$$\overrightarrow{A} = 2\vec{a}.\vec{r_1} - \vec{a}. \quad (\vec{r_1} : [0,1]) \tag{1}$$

WOA updates position of agents by Eqs. (2), (3) or (4).

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

$$\begin{cases} \overrightarrow{D} = |\overrightarrow{C}.\overrightarrow{X^*}(t) - \overrightarrow{X}(t)| \\ \overrightarrow{X}(t+1) = \overrightarrow{X}(t) - \overrightarrow{A}.\overrightarrow{D}. \end{cases} \tag{2}$$

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

$$\begin{cases} \overrightarrow{D'} = |\overrightarrow{X^*}(t) - \overrightarrow{X}(t)| \\ \overrightarrow{X}(t+1) = \overrightarrow{D'} e^{bl} \cos(2\pi l) + \overrightarrow{X^*}(\mathrm{t}). \end{cases} \tag{3}$$

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

$$\begin{cases} \overrightarrow{D_{rand}} = |\overrightarrow{X_{rand}} - \overrightarrow{X}(t)| \\ \overrightarrow{X}(t+1) = \overrightarrow{X_{rand}} - \overrightarrow{A}.\overrightarrow{D_{rand}}. \end{cases} \tag{4}$$

3. Proposed Method

The possibility that WOA finds local solution is high. We propose Whale Optimization Algorithm with Natural Enemy (WOANE) to escape from the local solution. In WOANE, when a search agent approaches a natural enemy agent, it searches globally. Natural enemy chases whales the farthest whales from optimal solution. Natural enemy moves according to Eq. (5) or (6).

$$\begin{cases} \overrightarrow{D} = |\overrightarrow{C}.\overrightarrow{X_w}(t) - \overrightarrow{X_e}(t)| \\ \overrightarrow{X_e}(t+1) = \overrightarrow{X_e}(t) - \overrightarrow{A}.\overrightarrow{D}. \end{cases} \quad (if\ p \le 0.5) \tag{5}$$

$$\begin{cases} \overrightarrow{D'} = |\overrightarrow{X^*}(t) - \overrightarrow{X_e}(t)| \\ \overrightarrow{X_e}(t+1) = \overrightarrow{D'} e^{bl} \cos(2\pi l) + \overrightarrow{X_w}(\mathrm{t}). \end{cases} \quad (if\ p > 0.5) \tag{6}$$

Where $\overrightarrow{X_e}$ is position of Natural enemy and $\overrightarrow{X_w}$ is position of the farthest whales from the optimal solution.

Whales escape from natural enemies under Eq. (7).

$$|\overrightarrow{X_e}(t) - \overrightarrow{X}(t)| < |\overrightarrow{X^*}(t) - \overrightarrow{X_w}(t)|. \tag{7}$$

In addition, the whale that once escaped from a natural enemy will not escape until the number of iterations increases by five. There are two types of whales chased by natural enemies. In the first type, chased whales move randomly within the search range. In the second type, the chased whale moves according to Eq. (8).

$$\begin{cases} \overrightarrow{D_{rand}} = 3|\overrightarrow{X_{rand}} - \overrightarrow{X}(t)| \\ \overrightarrow{X}(t+1) = \overrightarrow{X_{rand}} - \overrightarrow{A}.\overrightarrow{D_{rand}}. \end{cases} \tag{8}$$

4. Simulation Results

We compare WOANE 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]	-1.26×10^4
f_3	$\sum_{i=1}^{n} [{x_i}^2 - 10\cos(2\pi x_i) + 10]$	[-5.12,5.12]	0
f_4	$\frac{1}{4000}\sum_{i=1}^{n} {x_i}^2 - \prod_{i=1}^{n} \cos(\frac{x_i}{i})$	[-600,600]	0

Each numerical experiment runs 100 times. In each test function, we define $t_{max} = 2000$, $n = 30$. Average value and standard deviation are shown in Table 2.

Table 2: Results of WOA and the proposed method.

		WOA	WOANE (ramdom)	WOANE (Eq. (8))
f_1	ave	9.66×10^{-84}	1.06×10^{-78}	$\mathbf{9.63 \times 10^{-84}}$
	std	6.09×10^{-83}	1.04×10^{-77}	$\mathbf{6.09 \times 10^{-83}}$
f_2	ave	-7.22×10^3	-7.23×10^3	-7.27×10^3
	std	5.83×10^2	5.72×10^2	5.50×10^2
f_3	ave	1.20	**0.552**	**0.375**
	std	3.75	**2.48**	**1.64**
f_4	ave	9.90×10^{-3}	$\mathbf{6.53 \times 10^{-3}}$	$\mathbf{4.91 \times 10^{-3}}$
	std	2.37×10^{-2}	$\mathbf{1.26 \times 10^{-2}}$	$\mathbf{8.94 \times 10^{-2}}$

Both WOANE obtain better results than the conventional WOA in multimodal function. WOANE, in which whales escape randomly, obtain inferior results to the conventional one in unimodal function. One the other hand, WOANE that the whale escapes according to Eq. (7) obtain the same result as the conventional WOA in the unimodal function.

5. Conclusion

We proposed the new WOA considering that whales escape from the natural enemy 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.