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EDITOR:

Prof. Dr. Muhhamad Faisal

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DETAILED PARAMETER ANALYSIS FOR AFRICAN VULTURES OPTIMIZATION ALGORITHM

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ABSTRACT

Metaheuristic algorithms are of great importance in solving optimization problems. In this study, the newly proposed African Vulture Optimization algorithm (AVO) has been examined. The AVO algorithm mimics the life-styles of African vultures and was created by imitating the foraging and wandering behavior of African vultures. Six kinds of fixed parameters (P1, P2, P3, L1, L2, w) are used in the algorithm. While the original paper examined the effect of these parameter values on AVO for only six types of values, nine types of effects were examined in this study (L1={0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1}, L2={0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}, P1={0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}, P2={0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}, P3={0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}, w= {1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5}). The best parameter values were selected for AVO by examining the results. These parameters balance AVO's local and global search capabilities. According to the results, while the values of L1, L2, and w parameters were similar to the values in the original paper (L1=0.6, L2=0.4, and w=2.5), different appropriate values were determined for P1, P2, and P3 values (P1=0.4, P2=0.9, and P3=0.6).

Keywords: African vultures, Optimization, AVO

INTRODUCTION

Metaheuristic algorithms have attracted the attention of many researchers in recent years. The success of metaheuristic algorithms in solving continuous and discrete problems is the basis for this. Continuous optimization problems are usually very complex. Mathematical methods often cannot find the optimal solution. Metaheuristic algorithms, on the other hand, can produce more powerful results for the solutions of continuous optimization problems. Mathematical methods have been used to solve many scientific and engineering problems and cover a wide range of different topics, but mathematical methods, despite their precision, still face many difficulties in solving many optimization problems (Abdollahzadeh, et al., 2021). Metaheuristic algorithms are created by imitating many situations. For example, natural events, creatures living in the form of flocks, mathematical facts, etc. Inspired by many natural phenomena, the heuristic algorithm uses their exploration and exploitation abilities to search for food sources. The success of such algorithms lies in balancing exploration and exploitation capabilities.

In recent years, the newly proposed African Vulture Optimization (AVO) algorithm is a heuristic algorithm created by mathematically modeling the lifestyles of African vultures. In recent years, many studies have been done with AVO. Khodadadi et al. proposed a new multi-objective artificial vultures optimization algorithm (Khodadadi et al., 2022). Alanazi et al. proposed an optimal reconfiguration of shaded PV based system using African vultures optimization approach (Alanazi et al., 2022). Xiao et al. proposed an improved hybrid Aquila Optimizer and African vultures optimization algorithm for global optimization problems (Xiao et al., 2022). Kumar and Mary proposed a study about parameter estimation of three-diode solar photovoltaic model using an Improved-African Vultures optimization algorithm with Newton–Raphson method (Kumar and Mary, 2021). Xi et al. proposed Binary African vultures optimization algorithm for various optimization problems (Xi et al., 2022).

In this study, a study that analyzes its parameters for AVO is presented. These parameters balance AVO's local and global search capabilities. There are six kinds of control parameters on AVO. These are P1, P2, P3, L_1, L_2, and w. In the original paper of AVO, these values were suggested as 0.6, 0.4, 0.6, 0.8, 0.2, 2.5, respectively.

AFRICAN VULTURES OPTIMIZATION ALGORITHM

Vultures fall into two main categories. These are the new world vultures and the old world vultures. New-world vultures are found in America, while old-world vultures live in Europe, Asia, and Africa. The body of most vultures is not completely covered with feathers. There are no feathers on the neck and head. They feed on animal leaves. They don't nest. The basic principles of AVO to model AVO mathematically: (Khodadadi et al., 2022)

There are at most N (population numbers) vultures in a search space.

- The total number of vultures is divided into two main groups. In AVO, the fitness solutions of the whole population are first calculated. The first two best solutions are chosen and the first two vultures are determined. The remaining population members form a population that moves or replaces one of the two best vultures at each performance (Khodadadi et al., 2022).
- In AVO, the worst vulture is the weakest and most hungry vulture. Other vultures try to stay away from him. The best and strongest vulture are the first two vultures. Population members try to best approach the first two vultures (Khodadadi et al., 2022).

AVO is mathematically modeled in four steps.

First scene:

After the initial population is established, the fitness of all solutions is calculated and the best solution is chosen as the best vulture of the first group and the second best solution as the best vulture of the second group. Other population members try to move best towards the first two vultures. In each cycle, the fitness values are reapplied for the entire population. The work of approximating the best first two solutions of the other groups is calculated by Equation 1 (Khodadadi et al., 2022).

$$R(i) = \begin{cases} Vulture_{Best1} & if\ P_i = L_1 \\ Vulture_{Best2} & if\ P_i = L_2 \end{cases} \quad (1)$$

$$Subject:\ L_1 + L_2 = 1$$

$$P_i = \frac{F_i}{\sum_{i=1}^{n} F_i} \quad (2)$$

The probability of choosing one of the two best solutions is obtained by Equation 2 (Khodadadi et al., 2022). $Vulture_{Best1}$ is the first best vulture of the group and $Vulture_{Best2}$ is the second best vulture of group.

Second scene:

Equations 3-4 were used to move from the exploration stage to the exploitation stage, inspired by the saturation or hunger rates of the vultures. Vultures often forage for food, but fly longer distances if they are full. If a vulture is hungry, they don't have enough energy to fly for long periods and forage for food near the stronger vulture (Khodadadi et al., 2022). According to the $|F|$ value, it moves to the third scene or fourth scene. If $|F|$ value less than 1, AVO enters the exploration stage, otherwise AVO enters the exploitation stage (Khodadadi et al., 2022).

$$t = h \times \left(sin^w \left(\frac{\pi}{2} \times \frac{iter_i}{Max\_iter} \right) + cos \left(\frac{\pi}{2} \times \frac{iter_i}{Max\_iter} \right) - 1 \right) \quad (3)$$

$$F = (2 \times r_1 + 1) \times z \times \left(1 - \frac{iter_i}{Max_{iter}}\right) + 1 \tag{4}$$

F indicates that the vultures are satiated. $iter_i$ shows the current iteration number, Max_{iter} shows the maximum iteration number, z indicates a random number for range [-1, 1], h indicates a random number for range [-2, 2], and r_1 indicates a random number for range [0, 1] (Khodadadi et al., 2022).

<u>Third scene:</u> The exploration

At this stage, the discovery phase of AVOA is modeled. In the natural environment, vultures have high visual acuity and the ability to find food and spot poor dying animals. But finding food for vultures can be very difficult. Vultures carefully study their environment for a long time and travel long distances in search of food.

In AVO, vultures explore the search space based on two different situations. Here, the selection process for both states is made according to P1. The discovery process in AVO is shown in Equations 5-8 (Khodadadi et al., 2022).

$$P(i+1) = \begin{cases} Eq.(6) \;\; if \;\; P_1 \geq \; Rand_{P1} \\ Eq.(8) \; if \;\; P_1 < \; Rand_{P1} \end{cases} \tag{5}$$

$$P(i+1) = R(i) - D(i) \times F \tag{6}$$

$$D(i) = |X \times R(i) - P(i)| \tag{7}$$

$$P(i+1) = R(i) - F + \; r_2 \times ((ub - lb) \times r_3 + lb) \tag{8}$$

F is the rate of the vulture being satiated and it is obtained using Equation 4. $R(i)$ is obtained using Equation 1. X is a coefficient vector ($X = rand \times 2$; $rand$ indicates a random number for range [0, 1]). $P(i)$ is the current vector position of the vulture. r_2 and r_3 indicate a random number for range [0, 1]. ub and lb indicate upper and lower bounds (Khodadadi et al., 2022).

Fourth scene: The exploitation

In this subsection, local search operations are continued according to P2 and P3 values.

Exploitation 1: Exploitation 1 enters for AVO when the |F| value is between 1 and 0.5. Competition for Food is shown in Equations 10 and 11. The rotating flight of vultures is shown in Equations 12 and 13 (Khodadadi et al., 2022).

$$P(i+1) = \begin{cases} Eq.(10) \;\; if \;\; P_2 \geq \; Rand_{P2} \\ Eq.(13) \; if \;\; P_2 < \; Rand_{P2} \end{cases} \tag{9}$$

$$P(i+1) = D(i) \times F + (r_4) - d(t) \tag{10}$$

$$d(t) = R(i) - P(i) \tag{11}$$

$$S_1 = R(i) \times \left(\frac{r_5 \times P(i)}{2\pi}\right) \times cos(P(i)) \tag{12}$$

$$S_2 = R(i) \times \left(\frac{r_6 \times P(i)}{2\pi}\right) \times sin(P(i))$$

$$P(i+1) = R(i) - (S_1 + S_2) \tag{13}$$

F is the rate of the vulture being satiated and it is obtained using Equation 4. $R(i)$ is obtained using Equation 1. $D(i)$ is obtained using Equation 7. $P(i)$ is the current vector position of the vulture. r_4 , r_5, and r_6 indicate a random number for range [0, 1]. $d(t)$ represents the distance of the vulture to one of the best vultures of the two groups (Khodadadi et al., 2022).

Exploitation 2: Exploitation 2 enters for AVO when the |F| value is less than 0.5. Equations 15 and 16 have been used to formulate Exploitation 2 of vultures. The accumulation of several types of vultures over the food source is shown in Equations 15 and 16. Aggressive competition for food is shown in Equations 17 and 18 (Khodadadi et al., 2022).

$$P(i+1) = \begin{cases} Eq.(10) \ if \ P_3 \geq Rand_{P3} \\ Eq.(13) \ if \ P_3 < Rand_{P3} \end{cases} \tag{14}$$

$$A_1 = Vulture_{Best1}\ (i) - \frac{Vulture_{Best1}(i) \times P(i)}{Vulture_{Best1}(i) \times P(i)^2} \times F$$

$$A_2 = Vulture_{Best2}\ (i) - \frac{Vulture_{Best2}(i) \times P(i)}{Vulture_{Best2}(i) \times P(i)^2} \times F \tag{15}$$

$$P(i+1) = \frac{A_1 + A_2}{2} \tag{16}$$

$$P(i+1) = R(i) - |d(t)| \times F \times Levy(d) \tag{17}$$

$$LF(x) = 0.001 \times \frac{u \times \sigma}{|v|^{\frac{1}{\beta}}}, \sigma = \left(\frac{\Gamma\ (1+\beta) \times \sin(\frac{\pi\beta}{2})}{\Gamma(1+\beta 2) \times \beta \times 2(\frac{\beta-1}{2})}\right)^{\frac{1}{\beta}} \tag{18}$$

$Vulture_{Best1}$ is the best vulture of the first group and $Vulture_{Best2}$ is the best vulture of the second group. $P(i)$ is the current vector position of the vulture. F is the rate of the vulture being satiated and it is obtained using Equation 4. d represents the problem dimensions, u and v are random numbers between 0 and 1, and β is a fixed and default number of 1.5 (Khodadadi et al., 2022).

EXPERIMENTAL RESULTS AND ANALYSIS

AVO is coded on Matlab. The values selected for the parameter are shown in Table 1. In the original paper of AVO, L_1, L_2, P_1, P_2, P_3, and w were suggested as 0.6, 0.4, 0.6, 0.8, 0.2, and 2.5 respectively (Khodadadi et al., 2022). In order to see the effects of parameter values on AVO, each parameter was analyzed while other parameters were used as in the original paper. As a benchmark, the average (mean) calculation was made for each function. Each parameter value was run 10 times independently. Thirteen classical test functions, which are frequently used in the literature, were selected for testing. A population size, dimension, and maximum iteration were determined as 30, 30, and 100, respectively. Table 2 shows the results of L1 parameter values, Table 3 shows the results of L2 parameter values, Table 4 shows the results of P1 parameter values, Table 5 shows the results of P2 parameter values, Table 6 shows the results of P3 parameter values, and Table 7 shows the results of *w* parameter values.

According to the results, the most suitable values for L1 are 0.1 and 0.6, respectively and the most suitable values for L2 are 0.9 and 0.4, respectively. According to the results for P1, the most appropriate value was determined as 0.4. According to the results for P2, the most appropriate value was determined as 0.9. According to the results for P3, the most appropriate value was determined as 0.6. The most appropriate value for w was determined as 2.5 according to the results.

Table 1. The parameter values

Parameter									
L_1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
L_2	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
P_1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
P_2	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
P_3	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
w	1	1.5	2	2.5	3	3.5	4	4.5	5

Table 2. Analysis of L1 parameter values

F	L_1=0.9	L_1=0.8	L_1=0.7	L_1=0.6	L_1=0.5	L_1=0.4	L_1=0.3	L_1=0.2	L_1=0.1
F1	1,37E-43	5,44E-46	1,75E-48	3,02E-42	2,12E-40	1,59E-47	2,70E-42	5,81E-42	**5,38E-37**
F2	5,60E-24	2,62E-24	8,18E-27	**1,88E-20**	6,39E-22	8,78E-25	5,65E-21	1,09E-21	6,90E-20
F3	5,26E-37	3,42E-33	4,25E-29	3,00E-31	2,20E-29	8,71E-28	3,80E-31	**1,21E-24**	5,94E-24
F4	1,03E-24	4,84E-24	5,99E-22	5,62E-24	5,59E-24	6,38E-21	5,78E-22	6,20E-21	**2,88E-19**
F5	**8,98E-03**	2,80E+00	2,19E-02	5,70E+00	1,28E-02	1,57E-02	5,59E+00	2,78E-02	2,87E+00
F6	3,18E-02	**2,43E-02**	1,28E-01	6,94E-02	1,26E-01	3,97E-02	6,08E-02	3,99E-02	6,10E-02
F7	8,99E-04	1,12E-03	9,32E-04	1,01E-03	1,45E-03	5,82E-04	1,05E-03	6,92E-04	**5,46E-04**
F8	-1,17E+04	-1,21E+04	-1,16E+04	**-1,24E+04**	-1,19E+04	-1,19E+04	-1,20E+04	-1,18E+04	-1,20E+04
F9	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F10	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**
F11	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F12	1,19E-03	9,21E-04	1,56E-03	**4,37E-04**	2,80E-03	8,96E-04	1,80E-03	1,44E-03	1,59E-03
F13	2,23E-03	2,69E-02	2,25E-03	2,06E-02	8,38E-03	**3,59E-04**	9,17E-03	9,72E-03	8,82E-03

Table 3. Analysis of L2 parameter values

F	**L_2=0.1**	**L_2=0.2**	**L_2=0.3**	**L_2=0.4**	**L_2=0.5**	**L_2=0.6**	**L_2=0.7**	**L_2=0.8**	**L_2=0.9**
F1	1,37E-43	5,44E-46	1,75E-48	3,02E-42	2,12E-40	1,59E-47	2,70E-42	5,81E-42	**5,38E-37**
F2	5,60E-24	2,62E-24	8,18E-27	**1,88E-20**	6,39E-22	8,78E-25	5,65E-21	1,09E-21	6,90E-20
F3	5,26E-37	3,42E-33	4,25E-29	3,00E-31	2,20E-29	8,71E-28	3,80E-31	**1,21E-24**	5,94E-24
F4	1,03E-24	4,84E-24	5,99E-22	5,62E-24	5,59E-24	6,38E-21	5,78E-22	6,20E-21	**2,88E-19**
F5	**8,98E-03**	2,80E+00	2,19E-02	5,70E+00	1,28E-02	1,57E-02	5,59E+00	2,78E-02	2,87E+00
F6	3,18E-02	**2,43E-02**	1,28E-01	6,94E-02	1,26E-01	3,97E-02	6,08E-02	3,99E-02	6,10E-02
F7	8,99E-04	1,12E-03	9,32E-04	1,01E-03	1,45E-03	5,82E-04	1,05E-03	6,92E-04	**5,46E-04**
F8	-1,17E+04	-1,21E+04	-1,16E+04	**-1,24E+04**	-1,19E+04	-1,19E+04	-1,20E+04	-1,18E+04	-1,20E+04
F9	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F10	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**
F11	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F12	1,19E-03	9,21E-04	1,56E-03	**4,37E-04**	2,80E-03	8,96E-04	1,80E-03	1,44E-03	1,59E-03
F13	2,23E-03	2,69E-02	2,25E-03	2,06E-02	8,38E-03	**3,59E-04**	9,17E-03	9,72E-03	8,82E-03

Table 4. Analysis of P1 parameter values

F	**P_1=0.1**	**P_1=0.2**	**P_1=0.3**	**P_1=0.4**	**P_1=0.5**	**P_1=0.6**	**P_1=0.7**	**P_1=0.8**	**P_1=0.9**
F1	1,26E-49	1,85E-49	1,74E-43	2,00E-53	**8,89E-56**	5,68E-51	7,64E-50	7,80E-45	4,62E-50
F2	1,08E-24	4,33E-27	1,66E-27	**4,42E-29**	7,94E-26	8,90E-27	9,29E-28	2,60E-27	9,90E-26
F3	2,88E-34	8,07E-37	2,81E-32	**1,69E-38**	1,98E-31	1,67E-27	7,43E-31	1,38E-31	2,74E-29
F4	1,15E-26	1,08E-25	1,15E-25	5,83E-25	4,01E-25	1,12E-25	1,65E-24	1,13E-24	**8,99E-28**
F5	6,86E-03	1,34E-02	5,28E-03	**5,02E-03**	2,77E+00	3,04E-02	1,58E-02	1,13E+01	1,67E+01
F6	2,09E-02	2,12E-02	4,87E-02	**1,81E-02**	1,65E-01	6,57E-02	1,63E-01	9,03E-02	7,33E-02
F7	8,18E-04	1,10E-03	1,57E-03	6,82E-04	5,57E-04	**5,54E-04**	1,22E-03	6,50E-04	1,45E-03
F8	-1,08E+04	-1,19E+04	-1,18E+04	-1,16E+04	-1,13E+04	-1,20E+04	**-1,22E+04**	-1,21E+04	-1,13E+04
F9	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F10	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**
F11	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F12	9,36E-04	1,72E-04	7,55E-04	1,03E-03	4,79E-04	**1,65E-04**	3,23E-03	6,13E-04	2,17E-03
F13	1,52E-04	1,66E-04	1,07E-04	**2,09E-05**	9,15E-03	9,42E-03	1,72E-02	1,29E-02	2,20E-01

Table 5. Analysis of P2 parameter values

F	P_2=0.1	P_2=0.2	P_2=0.3	P_2=0.4	P_2=0.5	P_2=0.6	P_2=0.7	P_2=0.8	P_2=0.9
F1	2,69E-39	1,91E-37	3,50E-47	1,86E-47	1,26E-55	**2,16E-61**	8,53E-61	3,62E-60	3,57E-59
F2	4,97E-25	3,04E-24	1,77E-27	2,40E-27	1,97E-27	1,77E-30	6,69E-25	3,41E-27	**9,57E-33**
F3	7,03E-23	8,39E-26	4,12E-24	1,26E-34	4,63E-36	1,54E-37	8,04E-36	6,96E-45	**1,91E-45**
F4	1,05E-19	2,33E-23	2,18E-22	1,65E-28	1,99E-26	3,45E-29	2,01E-30	**4,21E-31**	8,79E-28
F5	1,20E-01	5,64E+00	4,15E-02	3,41E-02	2,81E+00	2,84E+00	1,84E-02	2,88E+00	**8,55E-03**
F6	5,32E-02	1,21E-01	2,14E-02	2,41E-02	**1,10E-02**	6,42E-02	2,86E-02	4,39E-02	4,72E-02
F7	1,04E-03	1,17E-03	5,59E-04	8,32E-04	1,08E-03	**5,34E-04**	1,23E-03	1,32E-03	7,94E-04
F8	-1,23E+04	**-1,24E+04**	-1,21E+04	-1,22E+04	**-1,24E+04**	-1,20E+04	-1,18E+04	-1,19E+04	-1,21E+04
F9	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F10	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**
F11	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F12	**8,91E-04**	1,39E-03	1,34E-03	2,35E-03	4,04E-03	3,08E-03	9,20E-04	2,16E-03	1,66E-03
F13	1,06E-02	4,99E-03	7,72E-04	2,29E-02	8,48E-03	8,24E-03	1,95E-05	**1,91E-05**	2,16E-05

Table 6. Analysis of P3 parameter values

F	P_3=0.1	P_3=0.2	P_3=0.3	P_3=0.4	P_3=0.5	P_3=0.6	P_3=0.7	P_3=0.8	P_3=0.9
F1	3,33E-30	9,10E-41	1,26E-36	9,75E-53	**4,87E-55**	7,07E-39	6,17E-48	3,18E-53	6,01E-48
F2	1,70E-22	3,04E-19	4,61E-22	3,40E-24	1,45E-24	**1,09E-28**	8,13E-28	7,77E-26	1,59E-26
F3	1,35E-08	3,07E-22	2,01E-26	6,26E-32	4,79E-25	1,38E-30	4,22E-32	1,34E-28	**9,76E-39**
F4	4,19E-13	6,18E-23	2,33E-20	1,82E-23	9,45E-27	3,74E-26	**2,24E-27**	7,60E-27	2,52E-24
F5	1,69E+01	5,59E+00	1,69E+01	8,39E+00	2,89E+00	**1,17E-02**	2,79E+00	5,66E+00	5,56E+00
F6	3,25E-01	2,56E-01	9,72E-02	6,62E-02	4,40E-02	7,32E-02	5,98E-02	**2,07E-02**	2,47E-02
F7	9,50E-04	7,95E-04	1,80E-03	9,14E-04	1,42E-03	**6,00E-04**	1,01E-03	6,43E-04	9,32E-04
F8	-1,17E+04	**-1,24E+04**	-1,08E+04	-1,20E+04	-1,22E+04	-1,12E+04	-1,18E+04	-1,17E+04	**-1,24E+04**
F9	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F10	1,24E-15	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**
F11	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F12	2,69E-03	4,03E-03	3,55E-03	1,03E-03	5,09E-03	3,27E-03	2,31E-03	**1,40E-04**	2,39E-03
F13	5,20E-02	2,34E-02	7,48E-02	1,83E-03	2,17E-02	2,32E-04	**5,92E-05**	6,45E-04	7,55E-03

Table 7. Analysis of w parameter values

F	w=1	w=1.5	w=2	w=2.5	w=3	w=3.5	w=4	w=4.5	w=5
F1	1,14E-40	1,33E-44	1,49E-43	**3,20E-52**	1,03E-48	2,03E-50	9,96E-44	1,88E-49	2,39E-50
F2	3,21E-23	1,05E-25	7,74E-24	1,20E-24	**1,86E-27**	4,07E-26	8,76E-23	5,54E-25	4,45E-27
F3	7,00E-34	1,72E-24	2,93E-33	5,01E-30	8,15E-31	**2,68E-34**	1,60E-22	4,86E-27	1,79E-28
F4	6,88E-24	3,58E-20	2,09E-23	**7,42E-27**	1,15E-25	8,67E-23	2,70E-26	1,88E-26	1,72E-26
F5	5,62E+00	9,19E-03	1,91E-02	5,65E+00	**4,05E-03**	9,01E-03	1,08E-02	2,78E+00	5,53E+00
F6	4,47E-02	2,64E-02	9,78E-02	3,54E-02	**7,76E-03**	8,09E-02	4,12E-02	7,09E-02	2,94E-02
F7	9,43E-04	1,16E-03	8,88E-04	8,03E-04	8,06E-04	7,62E-04	1,10E-03	8,87E-04	**5,47E-04**
F8	-1,22E+04	-1,20E+04	-1,18E+04	**-1,24E+04**	-1,17E+04	-1,21E+04	-1,18E+04	-1,20E+04	-1,23E+04
F9	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F10	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**	**8,88E-16**
F11	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**	**0,00E+00**
F12	8,85E-04	8,25E-04	1,53E-03	**4,95E-05**	1,50E-03	2,23E-03	2,49E-03	1,37E-03	1,58E-03
F13	1,02E-02	3,46E-03	3,74E-03	2,91E-03	1,50E-03	**7,37E-05**	4,27E-03	3,45E-03	3,64E-03

CONCLUSIONS

In this study, the newly proposed AVO algorithm in recent years has been examined. Six kinds of parameters that balance local and global search capabilities are used in the AVO algorithm. The effect of these parameters on AVO results is analyzed in detail in this paper. These parameters are: L1={0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1}, L2={0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}, P1={ 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}, P2={0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}, P3={0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9}, w= {1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5}. Their performance on thirteen classical test functions was evaluated. According to the results, the most suitable values for L1 are 0.1 and 0.6, respectively and the most suitable values for L2 are 0.9 and 0.4, respectively. According to the results for P1, the most appropriate value was determined as 0.4. According to the results for P2, the most appropriate value was determined as 0.9. According to the results for P3, the most appropriate value was determined as 0.6. The most appropriate value for w was determined as 2.5 according to the results.

Although L1, L2, P1, P2, P3, and w in the original article of AVO were suggested as 0.6, 0.4, 0.6, 0.8, 0.2, and 2.5, respectively, according to the results of this paper, they were determined as 0.6, 0.4, 0.4, 0.9, 0.6, and 2.5, respectively.

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