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**INVESTIGATION OF PSO-ALGORITHM SEARCH ABILITY
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In many areas of control, dynamical system analysis, signal processing, neural network training different optimization problems appear. Their investigation has brought to the development of a new class of nature-inspired optimization algorithms. One of the most powerful among them (in terms of localization of good solution of the problem) is particle swarm optimization (PSO) [1].

Many studies of PSO have shown, that minor improvements of canonical PSO algorithm may cause increasing of its search abilities [2]. The goal of the current investigation is connected with the further improvement of PSO algorithm and statistical analysis of the developed modification efficiency.

The main idea, which forms the basis of the proposed improvement is a rounding procedure in the stage of particle position updating. Indeed, in order to make the position of a particle more stochastic we recommend using the next formula:

$$x_{di} = \text{Round}(x_{d(i-1)} + v_{di}, n)$$

where i – the number of the current iteration ($i \in (\overline{1, I})$); I – the overall number of iterations; v_{di} and x_{di} – are components of the a particle position-vector and velocity-vector respectively for the d -th argument; n – the index, which shows the nearest multiple of the sum $x_{d(i-1)} + v_{di}$.

Variation of value n governs by the expression:

$$n = 10^r,$$

where r – is an integer number that generates in the interval from 1 to -10. The limits of variation have been set with no argumentation. However, in further works, we will ground them. *We will refer to the modified algorithm as PSO-Round.*

In order to show the efficiency of the *PSO-Round* we have solved several optimization problems. In the calculation, we have used four well-known benchmark functions to minimize, which are given in Table 1. The number of unknown arguments to find for all cases was 50.

Table 1. The set of the benchmarks

Benchmark function	Formula	Search domain	Value of the global minimum
Spherical	$f1 = \sum_{i=1}^D x_i^2$	$-20 \leq x_i \leq 20$	0
Rosenbrock	$f2 = \sum_{i=1}^{D-1} (100(x_{i+1} - x_i^2)^2 + (1 - x_i)^2)$	$-10 \leq x_i \leq 10$	0
Griewank	$f3 = 4000^{-1} \sum_{i=1}^D x_i^2 - \prod_{i=1}^D \cos(x_i i^{-0.5}) + 1$	$-100 \leq x_i \leq 100$	0
Alpine	$f4 = \sum_{i=1}^D x_i \sin(x_i) + 0.1x_i $	$-10 \leq x_i \leq 10$	0

In order to obtain statistically valid data, each of the optimization algorithms has launched 30 times. Statistical indicators were: min, max, median, and standard deviation values. They are given in Table 2.

Numerical data in Table 2 shows, that for the $f1$ and $f3$ benchmarks PSO-Round for all launches has found the global minimum. For the $f2$ benchmark, PSO-Round has shown better results, than canonical PSO. For the $f4$ benchmark, developed in the current study technique has decreased the efficiency of algorithm. However, we recommend continuing improvement the developed approach.

For instance, the n may change during algorithm execution by some dependence. The expression of the dependence is the object of further investigation in this direction.

Table 2. Numerical experiments outcome

Functions	Indicators	Algorithms	
		PSO	PSO-Round
$f1$	Max	137.754	0
	Min	7.46458	0
	Median	39.3997	0
	SD	36.1218	0
$f2$	Max	362.146	48.6725
	Min	110.845	46.2505
	Median	223.027	47.2857
	SD	57.3032	0.887148
$f3$	Max	0.0109412	0
	Min	0.00110295	0
	Median	0.0053051	0
	SD	0.00320284	0
$f4$	Max	22.2711	41.3018
	Min	4.91958	2.15937
	Median	9.77552	17.1251
	SD	5.06638	10.1997

References

- [1] J. Kennedy, R.C. Eberhart «Particle swarm optimization», Proceedings of the 1995 IEEE International Conference on Neural Networks, Vol. 4, pp. 1942-1948, 1995.
- [2] Yu. Romasevych, V. Loveikin «A novel multi-epoch particle swarm optimization technique», Cybernetics and Information Technologies, vol. 18(3), pp. 62-74, 2018.