An Improved Particle Swarm Optimization Method with Application to Multimodal Functions of Inverse Problems

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Abstract—Improvements that use new formulae and strategies in particle swarm optimization (PSO) methods are proposed for updating the particles' velocity and position, craziness, and the use of simple refinement searching scheme and so on to enhance their performances. Numerical results are given to validate the feasibility and demonstrate the merits of the proposed method.

I. A New Particle Swarm Optimization Method

In global optimizations study of electromagnetic (EM) devices, stochastic methods play a dominant role because most deterministic ones tend to converge into a local optimum and no universal stochastic method can be applied successfully to all design problems. Therefore, one has to revert to available stochastic optimal methods but it is important to ensure there is sufficient diversity in such algorithms. In this paper improvements on an available PSO algorithm are proposed to enable it to become a topical and robust global optimizer.

Formulae and Strategy for Velocity and Position Updating: To optimize the use of cognitive knowledge of a particle and the social experience of its neighbors as the velocity of a particle is dated, the reasoning ability of an intelligent community that compromises the influence of the two aforementioned factors is modeled. Moreover, in order to strike the best trade-off between the exploration and exploitation of the search process while avoiding the use of an awkward linear decreasing inertia weight [1], and to avoid the performance degradation due to the kinetic inertia of a flying particle, two new random parameters are proposed. Moreover, in order to consider the bounded parameter space of an engineering problem, another random parameter is also introduced when updating the particles' positions. At the iteration step k+1, the new formulae for updating the velocity vector $v_i(k+1)$ and the position vector $x_i(k+1)$ of the i^{th} particle, are, respectively,

$$v_d^i(k+1) = (2r_2-1)v_d^i(k) + r_3c_1r_1(p_d^i - x_d^i(k)) + r_3c_2(1-r_1)(g_d^i - x_d^i(k)) \quad (1)$$

$$v_d^i(k+1) = \frac{v_d^i(k+1)\cdot v_d^{\max}}{|v_d^i(k+1)} \quad (if\ |v_d^i(k+1)| > v_d^{\max})$$
$$v_d^i(k+1) = \frac{v_d^i(k+1)\cdot v_d^{\min}}{|v_d^i(k+1)|} \quad (if\ |v_d^i(k+1)| < v_d^{\min}) \quad (2)$$

$$x_d^i(k+1) = r_4x_d^i(k) + (1-r_4)v_d^i(k+1) \quad (3)$$

where, $p_i = (p_1^i, p_2^i, \cdots, p_D^i)$ is the best position that particle i has previously found, $g_i = (g_1^i, g_2^i, \cdots, g_D^i)$ is the group's best position that the neighborhood particles of particle i have ever found, $r_i(i=1,2,\cdots,4)$ is a random parameters selected uniformly from the interval [0,1].

Craziness: Birds often change directions suddenly during flocking and such 'craziness' is modeled in the proposed algorithm. More specially, before updating a particle's position using (3), its velocity is crazed by

$$v_d^i(k+1) = \begin{cases} v_d^i(k+1) & (r_5 \le P_{cr}) \\ Rand_d(r_5) & (r_5 > P_{cr}) \end{cases} \quad (4)$$

where, r_5 is a random parameter which is uniformly selected from the interval [0,1], $Rand_d(\bullet)$ is a function which is used to randomly generate the d^{th} component of the velocity of the particle i, P_{cr} is a predefined probability of craziness.

Exploitation Search: To refine the searches and to find improved solutions around the best solution searched thus so far in order to find a new global best solution, an intensifying search, which has the characteristics that reminisces a tabu search method around the specific particle, is proposed.

II. Numerical Example

The proposed algorithm is firstly used to solve a five dimensional mathematical function with around 15^5 local optima to highlight the enhancement in its global search ability. An optimization study on the geometry of the multi-sectional pole arc of a salient pole hydro-generator is also reported to elucidate its feasibility in practical inverse problems. Details about these two case studies are described in [2].

Table I gives the success rate of 100 independent runs of the proposed and the original PSO algorithms in finding the global optimal solution for example 1, and Table II presents the performance comparison of the proposed algorithm and a universal tabu search on a 300 MW hydro-generator of example 2. From the tables it can be seen that the robustness and advantages of the proposed algorithm are positively confirmed.

TABLE I
Performance Comparison of Different Optimal Methods on the Mathematical Function for 100 Independent Runs

Algorithms	Averaged iterations	Success rate
Original PSO	1248	1/100
Proposed PSO	1464	100/100

TABLE II
Geometry Optimization Results of a 300 MW Hydro-generator

Algorithms	R_1(m)	R_2(m)	X_1(m)	Y_1(m)	X_2(m)	Y_2(m)
Proposed	0.0532	1.7366	0.2570	5.6515	0.1950	5.1299
Tabu	0.0522	1.7376	0.2571	5.6510	0.1955	5.1302

III. References

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