Metaheuristic Optimization: Particle Swarm Optimization (PSO)

Adaptive and Cooperative Algorithms (ECE 457A)

ECE, MME, and MSCI Departments, University of Waterloo, ON, Canada

Course Instructor: Benyamin Ghojogh Fall 2023

Swarm Optimization: the Idea

- Some of the metaheuristic optimization algorithms are swarm optimization methods.
- In swarm methods, we have a **swarm of particles** which collaboratively try to find the global best in an optimization landscape.
- The swarm methods are usually (but not always) **bio-inspired** or **nature-inspired** algorithms where the particles behave like animals, birds, creatures, etc.
- A recent survey on nature-inspired optimization is published in 2023 [1].
- For example, a swarm method can be inspired by a flock of birds or group of fish.
- Many bio-inspired or swarm metaheuristic algorithms exist such as:
 - Particle Swarm Optimization (PSO): 1995 [2]
 - Ant colony: 1996 [3, 4]
 - Grey wolf optimizer: 2014 [5]
 - Whale optimization algorithm: 2016 [6]
 - Salp Swarm Algorithm: 2017 [7]
 - A scholar in this area: Seyedali Mirjalili, Torrens University Australia, Australia, https://scholar.google.com/citations?user=TJHmrREAAAAJ&hl=en&oi=sra

Particle Swarm Optimization: the Idea

- Particle Swarm Optimization (PSO) was proposed in 1995 [2].
- The idea of PSO is like finding a treasure by a group of people.



• It is inspired a flock of birds or group of fish. Hence, it can be seen as one of the **bio-inspired** metaheuristic algorithms or **swarm optimization**.

Particle Swarm Optimization: the Formula

- The candidate solutions are the particles (vectors).
- Every particle searches locally in a local neighborhood. •
- Three components for the velocity vector for updating the solution:
 - the momentum (history) of previous velocity (fro exploitation): $\alpha_1 \mathbf{v}_i^{(k)}$

 - update according to the local best in the iteration: α₂(x^(k)_{localBest} x^(k)_i)
 update according to the global best in the iteration: α₃(x^(k)_{globalBest} x^(k)_i)
- The update of every particle:

$$\mathbf{v}_{i}^{(k+1)} := \alpha_{1} \mathbf{v}_{i}^{(k)} + \alpha_{2} (\mathbf{x}_{\text{localBest}}^{(k)} - \mathbf{x}_{i}^{(k)}) + \alpha_{3} (\mathbf{x}_{\text{globalBest}}^{(k)} - \mathbf{x}_{i}^{(k)}), \tag{1}$$

$$\mathbf{x}_{i}^{(k+1)} := \mathbf{x}_{i}^{(k)} + \mathbf{v}_{i}^{(k+1)}.$$
(2)

where α_1 , α_2 , and α_3 are weight (regularization) hyper-parameters.

- Variants of PSO:
 - local best:
 - Iocal best of particle itself in this iteration
 - ★ local best of particle itself so far (in all iterations until now)
 - global best:
 - ★ global best of all iterations so far (best found solution so far)
 - ★ best of solutions found by particles in this iteration

Particle Swarm Optimization: Visualizing the Formula

$$\mathbf{v}_{i}^{(k+1)} := \alpha_{1}\mathbf{v}_{i}^{(k)} + \alpha_{2}(\mathbf{x}_{\text{localBest}}^{(k)} - \mathbf{x}_{i}^{(k)}) + \alpha_{3}(\mathbf{x}_{\text{globalBest}}^{(k)} - \mathbf{x}_{i}^{(k)}),$$

$$\mathbf{x}_{i}^{(k+1)} := \mathbf{x}_{i}^{(k)} + \mathbf{v}_{i}^{(k+1)}.$$

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$$\mathbf{x}_{i}^{(k)} = \mathbf{x}_{i}^{(k)} + \mathbf{x}_{i}^$$

Particle Swarm Optimization: Flowchart



Acknowledgment

- Some slides of this slide deck are inspired by teachings of Prof. Saeed Sharifian at the Amirkabir University of Technology, Department of Electrical Engineering.
- A good web link about PSO: https://www.analyticsvidhya.com/blog/2021/10/ an-introduction-to-particle-swarm-optimization-algorithm/

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