Understanding Particle Swarm Optimization (PSO)

Simple Intuition with Step-by-Step Example

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What is PSO?

- A method to **find the best solution** by simulating how birds or fish search for food.
- Each **particle** is one guess (solution).
- Particles learn from:
  - Their own best guess so far (**pBest**)
  - The best guess anyone has made (**gBest**)

Key PSO Concepts

Term	**Meaning**
Particle	A solution guess
Position	Current value of the guess
Velocity	How fast the guess changes
pBest	Best solution found by particle
gBest	Best solution found by swarm

PSO Update Equations (Simplified)

Velocity Update:

$$v = v + c_1 \cdot r_1 \cdot (pBest - x) + c_2 \cdot r_2 \cdot (gBest - x)$$

Position Update:

$$x = x + v$$

Example 1: Find Minimum of $f(x) = x^2$

- **Goal:** Find the value of x that minimizes $f(x) = x^2$
- **Expected Answer:** $x = 0$

Step 1 – Initialize Particles

Assume 3 particles:

Particle	**Initial x**	**Initial v**	**pBest**
P1	4	0	4
P2	-2	0	-2
P3	3	0	3

Evaluate fitness: $f(4) = 16$, $f(-2) = 4$, $f(3) = 9$

$\Rightarrow$ **gBest = -2**

Step 2 – Update Velocity and Position (P1)

Assume: $c_1 = c_2 = 1.5,\ r_1 = 0.5,\ r_2 = 0.7$

$$v = 0 + 1.5 \cdot 0.5 \cdot (4 - 4) + 1.5 \cdot 0.7 \cdot (-2 - 4)$$

$$v = 0 + 0 - 6.3 = -6.3$$

$$x = 4 - 6.3 = \textbf{-2.3}$$

Evaluate fitness: $f(-2.3) = 5.29$ (worse than $f(-2) = 4$)

Update:

- pBest (P1) updated to -2.3 since $f(-2.3) < f(4)$.
- gBest remains at -2 (best overall so far).

Repeat Iterations

- Update remaining particles using same steps.
- Track gBest across iterations.
- Stop when improvement becomes small.

Final Result

- After a few steps, gBest ≈ 0
- **Minimum of** $f(x) = x^2$ **is at** $x = 0$

Example 2: Find Shortest Delivery Route (VRP)

- Each particle represents a delivery route.
- PSO searches different route combinations.
- Fitness = total distance of the route.
- **Goal:** Minimize delivery cost.

Example 3: Tune ML Hyperparameters

- Use PSO to tune SVM parameters [C, gamma].
- Each particle = a combination of parameters.
- Fitness = accuracy from cross-validation.
- **Goal:** Maximize model accuracy.

Summary

- PSO is a simple and effective optimizer.
- Based on social learning (self + swarm).
- Can solve a variety of problems.

Q & A

Any questions?