Computational Intelligence

Unit # 10

Particle Swarm Optimization

- Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling.
- The system is initialized with a population of random solutions and searches for optima by updating generations.
- Unlike EA, PSO has no evolution operators such as crossover and mutation.

Concept

- As stated before, PSO simulates the behaviors of bird flocking. Suppose the following scenario: a group of birds are randomly searching food in an area. There is only one piece of food in the area being searched. All the birds do not know where the food is. But they know how far the food is in each iteration. So what's the best strategy to find the food?
- The effective one is to follow the bird which is nearest to the food.

Algorithm Description

- In PSO, each single solution is a "bird" in the search space. We call it "particle".
- All of particles have fitness values which are evaluated by the fitness function to be optimized, and have velocities which direct the flying of the particles.
- The particles fly through the problem space by following the current optimum particles.
- PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations.

Algorithm Description

- Each particle keeps track of its coordinates in the problem space which are associated with the best solution (fitness) it has achieved so far. (The fitness value is also stored.) This value is called *pbest*.
- Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the neighbors of the particle. This location is called *lbest*.
- When a particle takes all the population as its topological neighbors, the best value is a global best and is called *gbest*.

Algorithm Description (Cont'd)

- At each step of the algorithm, particles are displaced from their current position by applying a velocity (gradient) vector to them.
- The magnitude and direction of their velocity at each step is influenced by their velocity in the previous iteration of the algorithm, simulated momentum, and the location of the a particle relative to the location of its pbest and the gbest.
- Therefore, at each step, the size and direction of each particle's move is a function of its own history (experience), and the social influence of its peer group.

Algorithm Description (Cont'd)

- After finding the two best values, the particle updates its velocity and positions with following equation (a) and (b).
- v[ ] = φ v[ ] + c1 * rand() * (pbest[ ] - present[ ])
  + c2 * rand() * (gbest[ ] - present[ ]) (a)
  present[] = present[ ] + v[ ] (b)

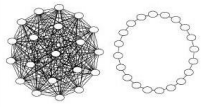
v[ ] is the particle velocity, persent[] is the current particle (solution). pbest[ ] and gbest[ ] are defined as stated before. rand () is a random number between (0,1). c1, c2 are learning factors, also known as acceleration constants (usually c1 = c2 = 2). φ is inertia weight.

Basic Theme

- The particle swarm optimization concept consists of, at each time step, changing the velocity of (accelerating) each particle toward its p*best* and *lbest* locations (local version of PSO).
- Acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward *pbest* and *lbest* locations.

Neighborhood Topologies

- **Star:** In the gbest swarm, all the particles are neighbors of each other; thus, the position of the best overall particle in the swarm is used in the social term of the velocity update equation. It is assumed that gbest swarms converge fast, as all the particles are attracted simultaneously to the best part of the search space. However, if the global optimum is not close to the best particle, it may be impossible to the swarm to explore other areas; this means that the swarm can be trapped in local optima.
- **Ring:** In the lbest swarm, only a specific number of particles (neighbor count) can affect the velocity of a given particle. The swarm will converge slower but can locate the global optimum with a greater chance



Role of pbest and gbest

- At the start of the algorithm, the pbest for each particle is set at its initial location, and gbest is set to the location of the best of the pbests.
- In each iteration of the algorithm, a particle is stochastically accelerated towards its previous best position and towards a neighborhood (global) best position, thereby forcing particles to continually search in the most-promising regions found so far in the solution space.

Role of c1 and c2

- The weight coefficient c1 and c2 control the relative impact of the pbest and gbest locations on the velocity of a particle.
- Low values for c1 and c2 allow each particle to explore far away from already uncovered good points, high values of the parameters encourage more intensive search of regions close to these points.

Comparing PSO with the EA

- Like the EA, PSO is population-based, it is typically initialized with a population (swarm) of random encodings of solutions, and search proceeds by updating these encodings over a series of generations (iterations).
- Both systems do not guarantee success.
- Both algorithms start with a group of a randomly generated population, both have fitness values to evaluate the population.
- Unlike the EA, PSO has no explicit selection process as all particles persist over time. Instead a *memory* in the form of gbest/lbest is substituted for selection.
- PSO also does not have genetic operators like crossover and mutation.

Comparing PSO with the EA (Cont'd)

- Compared with evolutionary algorithms (EAs), the information sharing mechanism in PSO is significantly different.
- In EAs, chromosomes share information with each other. So the whole population moves like a one group towards an optimal area.
- In PSO, only gBest (or lBest) gives out the information to others. It is a one -way information sharing mechanism. The evolution only looks for the best solution.
- Compared with EA, all the particles tend to converge to the best solution quickly even in the local version in most cases.