

Particle Swarm Optimization: a parallelized approach

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Abstract—*Particle Swarm Optimization* is an optimization algorithm for nonlinear function based on birds swarm. It falls back into the sub-field of *Bio-Inspired Artificial Intelligence* and it was designed from a simplified social model inspired by the nature.

A key concept associated with PSO is the role of genetic algorithms and evolution, the functioning is based on several iterations that aim to identify the best possible position represented as a point in a landscape.

The goal of this project is to design a parallelized implementation capable of exploring the solution space in a faster way. This is done though the usage of two main libraries for *High Performance Computing (HPC)*: *OpenMPI* and *OpenMP*.

The effectiveness of the proposed solution is tested using the HPC cluster of the University of Trento among other implementations found online.

Index Terms—ParticleSwarmOptimization; PSO; OpenMPI; OpenMP; C; Bio-Inspired; HPC; Parallelization

I. INTRODUCTION

Particle Swarm Optimization focuses on main definitions: the notion of *particle* and the one of *particle perception*. A particle can be seen as an entity which is characterized by:

- a position x depicting the *candidate solution* for our optimization problem;
- a velocity component v , which is used in order to *perturb* the particle;
- a performance measure $f(x)$, also called *fitness* value, which quantify the quality of the candidate solution.

The entire set of particles is referred as *swarm*.

Under the expression *particle perception*, we define how each particle communicate with each other. In practice, a particle needs to perceive the positions along with the associated performance measures of the *neighboring particles*. Thanks to this communication pattern, each particle remembers the position z associated to the best performance of all the particles within the neighborhood, as well as its own position where it obtained the best performance so far y .

This project implements a version of PSO considering *distance-based* neighborhood in a nearest neighbor fashion. In details, each particle has a fixed number of neighbors, which depend dynamically on the particle position on the landscape. The program offers the user the possibility to modify the number of particles to consider within a particle neighborhood.

A. Parametrization

In order to assess a solution for an optimization problem, PSO requires the following parameters to be set:

- *Swarm size*: typically 20 particles for problems with dimensionality 2-200;

- *Neighborhood size*: typically 3 to 5, otherwise global neighborhood;
- *Velocity update factors*.

B. Continuous Optimization

Once the algorithm has been parametrized, a swarm of particles is initialized with random positions and velocity.

At each step, each particle updates first its velocity:

$$v' = w \cdot v + \phi_1 U_1 \cdot (y - x) + \phi_2 U_2 \cdot (z - x)$$

where:

- x and v are the particle current position and velocity, respectively;
- y and z are the personal and social/global best position, respectively;
- w is the inertia (weighs the current velocity);
- ϕ_1, ϕ_2 are acceleration coefficients/learning rates (cognitive and social, respectively);
- U_1 and U_2 are uniform random numbers in $[0, 1]$.

Finally, each particle updates its position: $x' = x + v'$; and in case of improvement, update y (and eventually z).

The pseudocode of the algorithm is shown below:

Algorithm 1 Particle Swarm Optimization (Nearest Neighbors)

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1: function PSO( $\mathcal{S}, \mathcal{D}, MAX\_IT, n, f, v, x, x_{min}, x_{max},$ 
    $v_{max}$ )
2:   INITIALIZE( $\mathcal{S}, \mathcal{D}, f, v, x, x_{min}, x_{max}, v_{max}$ )
3:    $it = 0$ 
4:   repeat
5:     for each particle  $i \in \mathcal{S}$  do
6:       if  $f(x_i) < f(pb_i)$  then
7:          $pb_i \leftarrow x_i$ 
8:       end if
9:     end for
10:     $\mathcal{S}' = \text{COPY}(\mathcal{S})$ 
11:    for each particle  $i \in \mathcal{S}$  do
12:       $\mathcal{S}' = \text{SORT}(\mathcal{S}', i)$ 
13:      for each particle  $j \in \mathcal{S}'$  do
14:        if  $f(x_j) < f(gb_i)$  then
15:           $gb_i \leftarrow x_j$ 
16:        end if
17:      end for
18:    end for
19:    for each particle  $i \in \mathcal{S}$  do
20:      for each dimension  $d \in \mathcal{D}$  do
21:         $v_{i,d} = v_{i,d} + C_1 \cdot \text{Rnd}(0, 1) \cdot [pb_{i,d} - x_{i,d}] + C_2 \cdot$ 
         $\text{Rnd}(0, 1) \cdot [gb_d - x_{i,d}]$ 
22:         $x_{i,d} = x_{i,d} + v_{i,d}$ 
23:      end for
24:    end for
25:     $it \leftarrow it + 1$ 
26:  until  $it < MAX\_ITERATIONS$ 
27:  return  $x$ 
28: end function

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V. CONCLUSION

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VI. REFERENCES

C. State-of-the-art analysis

II. METHOD

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