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 ot 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)

function PSO($\mathcal{S}$, $\mathcal{D}$, MAX_IT, n, f, v, x, x_{min}, x_{max}, v_{max})
  INITIALIZE($\mathcal{S}$, $\mathcal{D}$, f, v, x, x_{min}, x_{max}, v_{max})
  $it = 0$
  repeat
    for each particle $i \in \mathcal{S}$ **do**
      if $f(x_i) < f(pb_i)$ **then**
        $pb_i \leftarrow x_i$
      end if
    end for
    $\mathcal{S}' = $ COPY($\mathcal{S}$)
    for each particle $i \in \mathcal{S}$ **do**
      $\mathcal{S}' = $ SORT(S', i)
      for each particle $j \in \mathcal{S}'$ **do**
        if $f(x_j) < f(gb_i)$ **then**
          $gb_i \leftarrow x_j$
        end if
      end for
    end for
    for each particle $i \in \mathcal{S}$ **do**
      for each dimension $d \in \mathcal{D}$ **do**
        $v_{i,d} = v_{i,d} + C_1 \cdot Rnd(0,1) \cdot [pb_{i,d} - x_{i,d}] + C_2 \cdot Rnd(0,1) \cdot [gb_d - x_{i,d}]$
        $x_{i,d} = x_{i,d} + v_{i,d}$
      end for
    end for
    $it \leftarrow it + 1$
  until it < MAX_ITERATIONS
  return x
end function

C. State-of-the-art analysis

II. Method

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III. Footnotes

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IV. Cites

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V. Conclusion

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VI. References