# Particle Swarm Optimization

## A parallelized approach

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# Introduction

## Particle Swarm Optimization

Particle Swarm Optimization is an optimization algorithm for nonlinear functions based on bird swarms.

In PSO, a particle is characterized by:

- position $x$;
- velocity $v$;
- performance measure $f(x)$;
- personal best $y$;
- global best position $z$.

The solution is achieved by perturbing each particle according to the neighbors:

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

# Particle Swarm Optimization

## Easom function

$$f(x) = -\cos(x_1)\cos(x_2)\exp(-(x_1-\pi)^2-(x_2-\pi)^2)$$

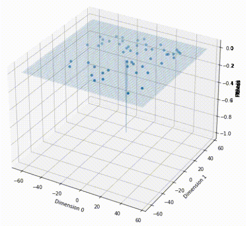



Figure 1: PSO start

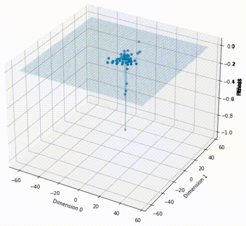



Figure 2: PSO mid

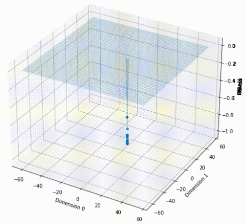



Figure 3: PSO end

# DevOps

Work in progress...

# Analyzing the program behavior

In order to know each process and thread state and visualize we have employed a thread-safe logging library: The logs follows a common pattern so as to be easily processed.

```
15:27:58 DEBUG : PSODATA    :: problem dimension :: 2
...
15:27:58 DEBUG : New best global solution found
...
15:27:58 INFO  : COMPUTING  :: iteration 10/10
Best fitness 4.690962
```

To recover the particles' positions during the entire program execution, we have stored each particle position at each iteration within a SQLite database.

# Serial version of the algorithm

**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**
        $\mathcal{S}' = \text{Copy}(\mathcal{S})$
        **for each** particle $i \in \mathcal{S}$ **do**
            $\mathcal{S}' = \text{Sort}$(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**

# Hybrid parallelization

We propose an all-to-all parallel computational pattern using `MPI_Allgather`.

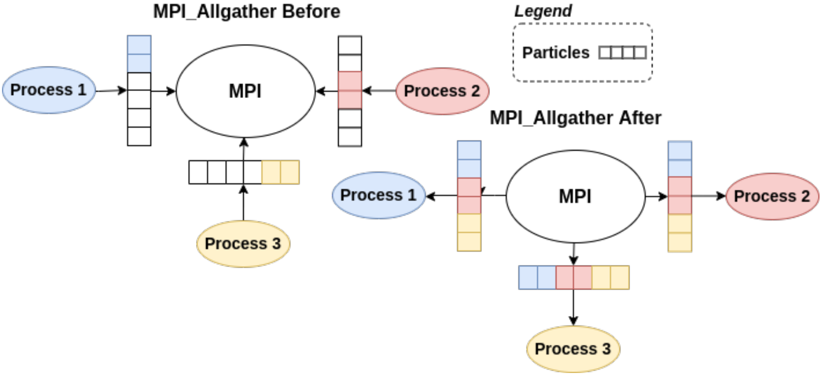
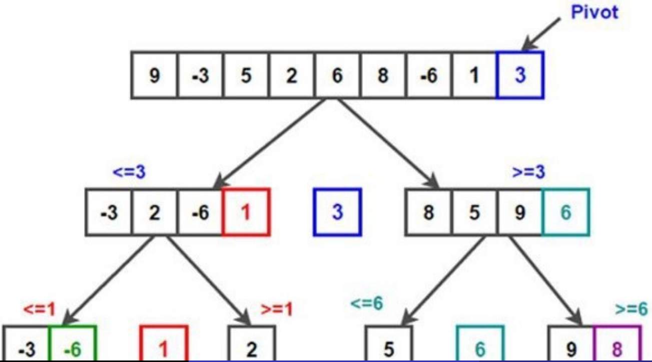



Figure 4: Parallel Architecture

# Hybrid parallelization (cont'd)

Once each process knows everything about the others, PSO considers the neighbor contributions in order to update the process particles' position and velocity.

To compute the particle's neighboring positions we have employed the quicksort algorithm.



# Benchmarking, first conclusions

The problem we have decided to address consists in solving the sphere function $\left( f(x_1, x_2, \ldots, x_n) = \sum_{i=1}^{n} x_i^2 \right)$ with:

- 50 particle dimensions;
- 500 iterations;
- 5000 particles.

We have run around 1280 tests considering every possible combination of different parameters:

- processes: `[1 2 4 8 16 32 64]`;
- threads: `[1 2 4 8 16 32 64]`;
- chunks: `[1 2 3 4 5]`;
- places: `[pack scatter pack:excl scatter:excl]`.

# Benchmarking, first conclusions (cont'd)

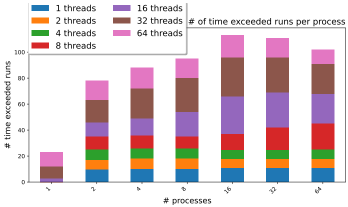



Figure 6: Number of failed run per process

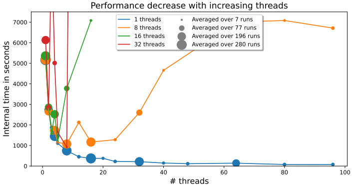



Figure 7: Thread and time exceeded correlation

# Benchmarking, first conclusions (cont'd)

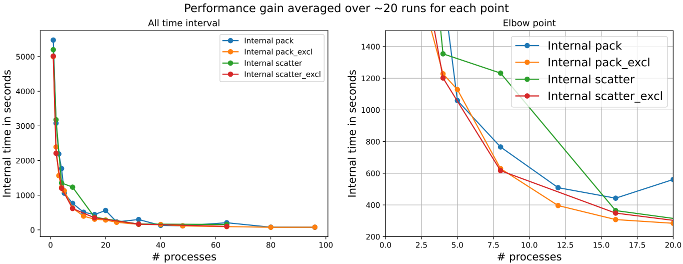



Figure 8: Processes performance

# State of the Art Analysis

| Ref. | Year | Type | Code | Note |
|---|---|---|---|---|
| Kennedy et al. (1995) | 1995 | Serial | No | - |
| toddguant (2019) | 2019 | Serial | Yes | 1 |
| souusouho (2019) | 2019 | Serial | Yes | 1 |
| kkentzo (2020) | 2020 | Serial | Yes | 1 |
| fisherling (2020) | 2020 | Serial | Yes | 1 |
| Moraes et al. (2015) | 2014 | MPI | No | - |
| Nedja et al. (2017) | 2017 | MPI/MP | No | - |
| abhi4578 (2019) | 2019 | MPI/MP,CUDA | Yes | 1 |
| LaSEEB (2020) | 2020 | OpenMP | Yes | 2 |
| pg443 (2021) | 2021 | Serial,OpenMP | Yes | 1 |

Note: (1) only global neighborhood (2) several option but not

# Benchmarking, final remarks

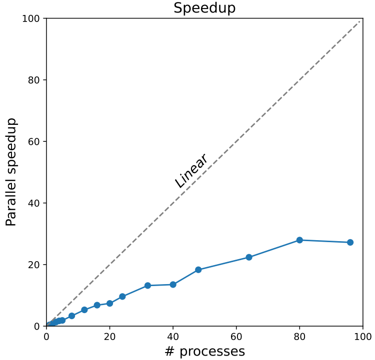



Figure 9: Speedup

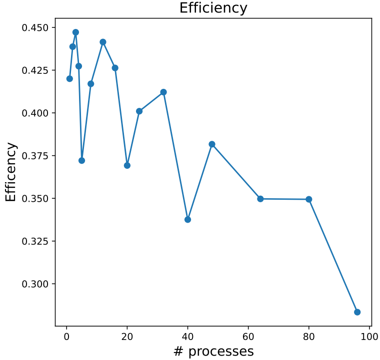



Figure 10: Efficiency

# Conclusion and future work

Up until this point, we produced a hybrid OpenMP-MPI algorithm to solve complex continuous optimization problems.

From the benchmarking analysis we claim:

- thread parallelization does not fit well our solution;
- benchmarking the algorithm is far from being trivial;
- the program provides its best result when the number of processes is limited.

As a future work, it would be interesting to:

- complement the already present architecture with different type of neighborhood;
- analyze which configuration brought the best results.

abhi4578. 2019. "Parallelization-of-PSO." https://github.com/abhi4578/Parallelization-of-PSO.

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Kennedy, J., and R. Eberhart. 1995. "Particle Swarm Optimization." In *Proceedings of ICNN'95 - International Conference on Neural Networks*, 4:1942–1948 vol.4. https://doi.org/10.1109/ICNN.1995.488968.

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# References II


Nedjah, Nadia, Rogério de Moraes Calazan, and Luiza de Macedo Mourelle. 2017. "A Fine-Grained Parallel Particle Swarm Optimization on Many-Core and Multi-Core Architectures." In *Parallel Computing Technologies*, edited by Victor Malyshkin, 215–24. Cham: Springer International Publishing.

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