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An OpenMP Parallel Genetic Algorithm for Design Space Exploration of Heterogeneous Multi-processor Embedded Systems

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Outline

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2. Design Space Exploration Context
3. Research Questions
4. Proposed Parallel Genetic Algorithm
5. Methodology and Scenarios
6. Experimental Results
7. Conclusion And Future Work

1. Introduction

Introduction

- The most critical issues into an HW/SW Co-Design methodology is always related to Design Space Exploration (DSE) activities.
- DSE is related to the approach, whether automated or not, used in order to find the best HW/SW partitioning and mapping for the final system implementation.
- These approaches usually rely on optimization problems, more than one objective function that can be considered (i.e., minimize cost, power consumption, maximize performance, throughput, etc.)
- A classical approach to solve an Multi-objective optimization problems (MOOP) is the Weighted Sum Method (WSM), which assigns a weight to each objective function

2.
Design Space Exploration Context

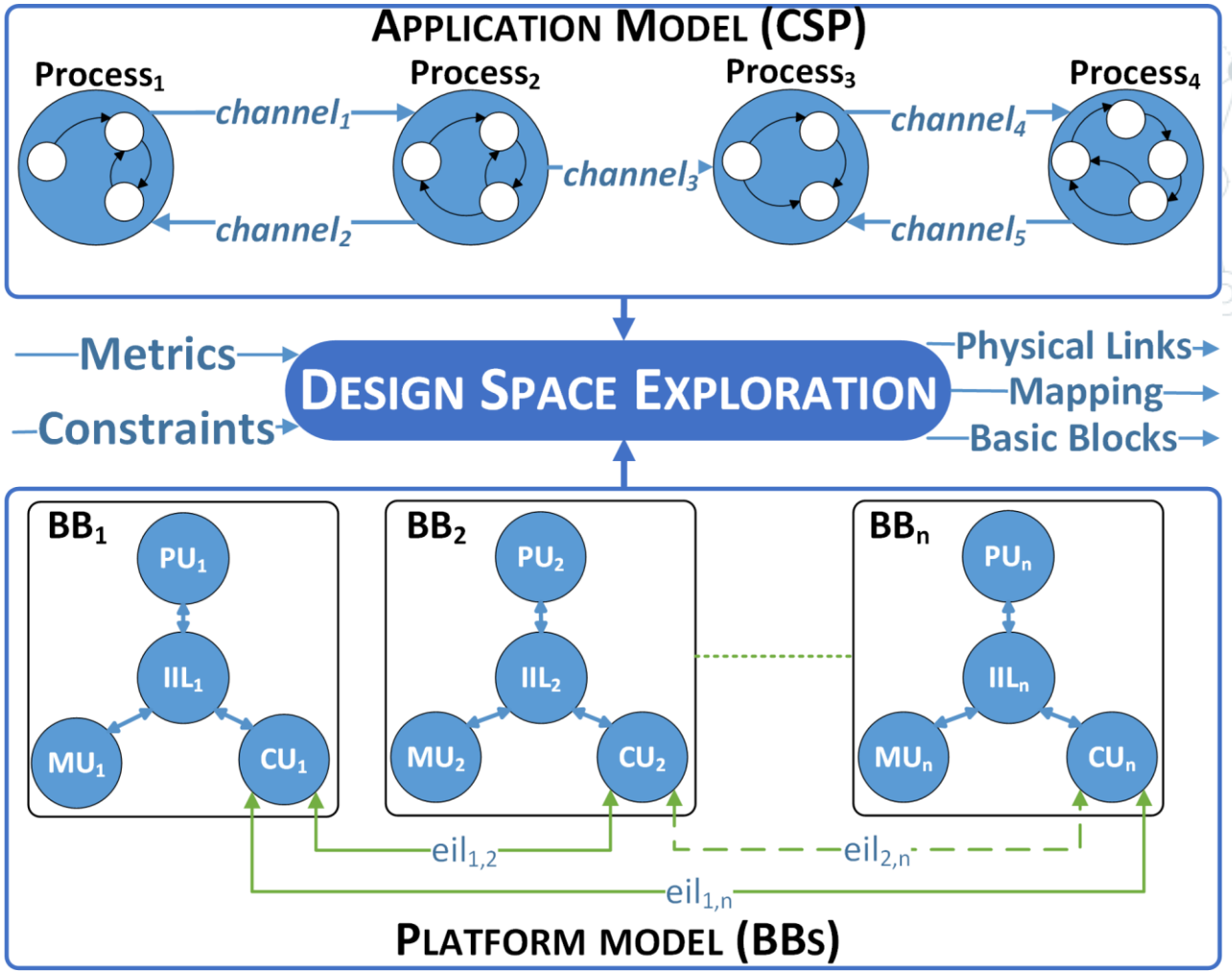
Design Space Exploration Context

INPUT:

- **Application Model:** CSP model injected with safety requirements.
- **Platform Model:** subset of HW solution (also in a multi-core scenario)
- **Metrics:** results from the Evaluation&Estimation activity
- **Constraints:** F/NF constraints (depending on application domain)

OUTPUT:

- **Physical Links:** Possible optimal links and topology.
- **Mapping:** Process to BBs.
- **Basic Blocks:** Processors, architecture and number of cores.



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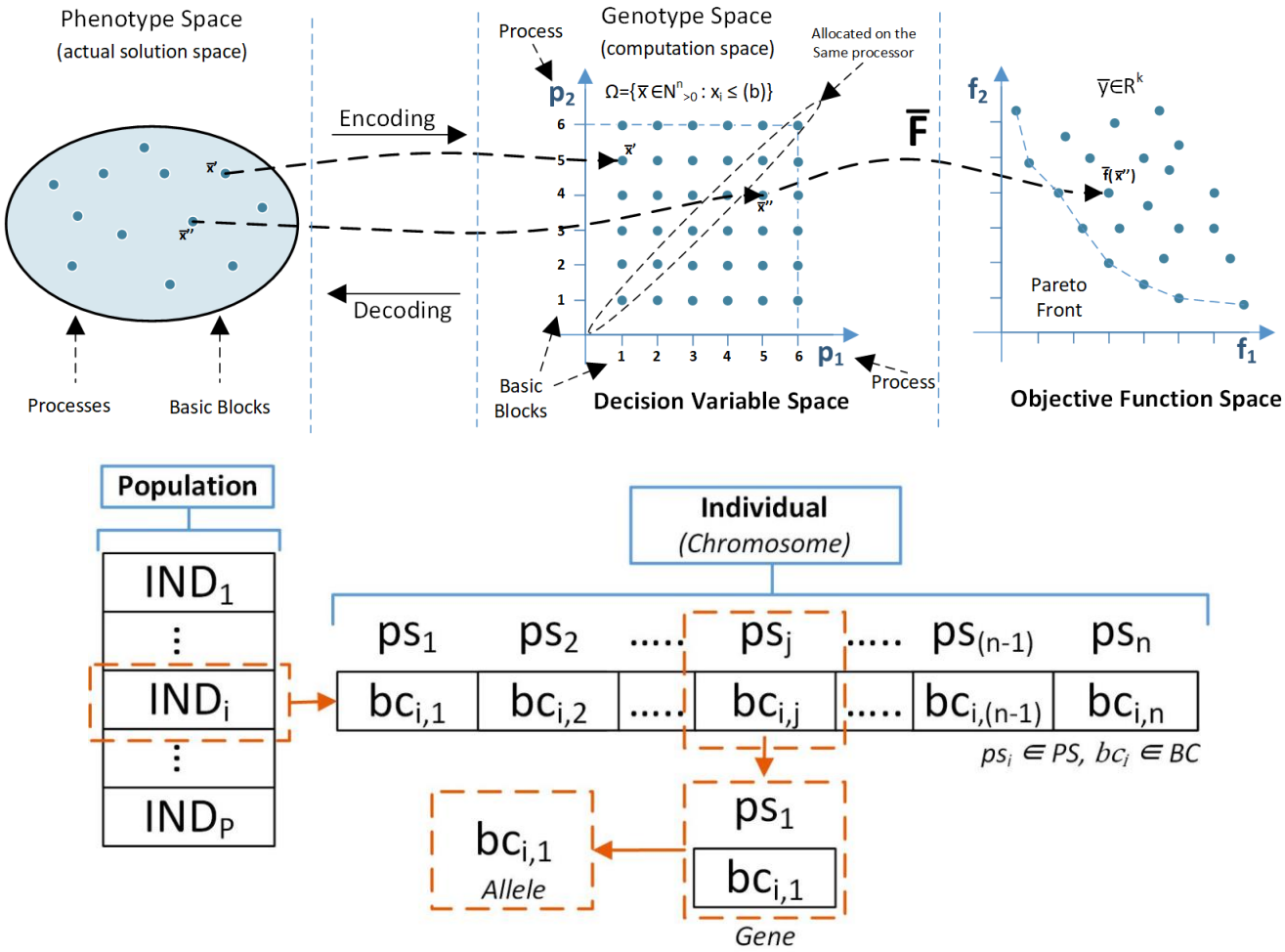
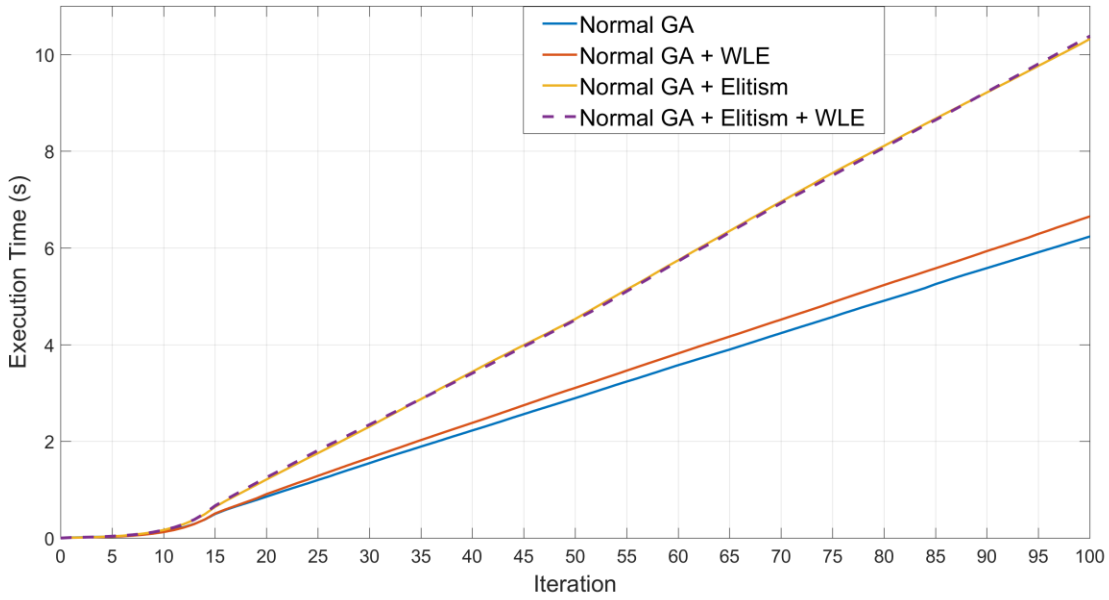


3. Research Questions

Research Questions

- **RQ1**: How is possible to reduce automatic DSE-GA execution time without loss of accuracy and diversity?
- **RQ2**: Which paradigm can be used in order to guarantee bounded timing behavior?
- **RQ3**: In which manner the automatic DSE configuration drives the choice of the possible algorithm implementations?



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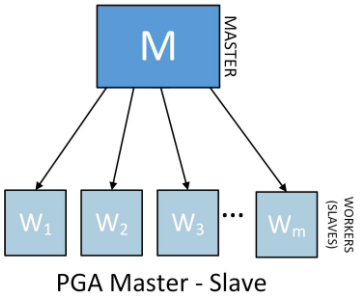
PARALLEL GENETIC ALGORITHM (PGA)

4.

Proposed Parallel Genetic Algorithm

Proposed Parallel Genetic Algorithm

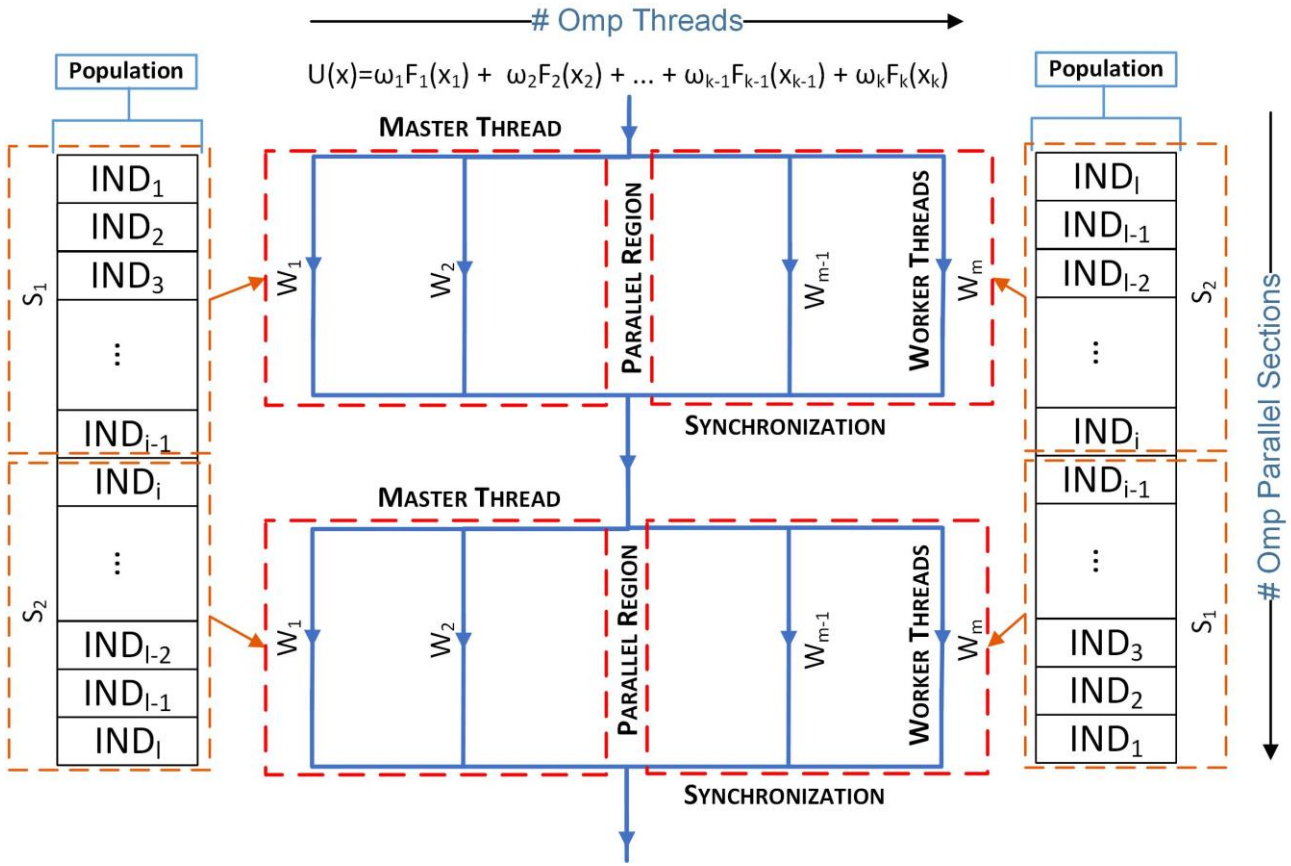
Global parallelization has been implemented, with a master-slave PGA approach.



PGA Master - Slave

3 types of PGA implementation:

- **Type 1**: Parallel evaluation of objective functions for each individual (evaluates objective functions on different threads);
- **Type 2**: Parallel evaluation of utility function (split the population into subsets);
- **Type 3**: Hybrid approach, combining the previous two approaches.



5.
Methodology and Scenarios

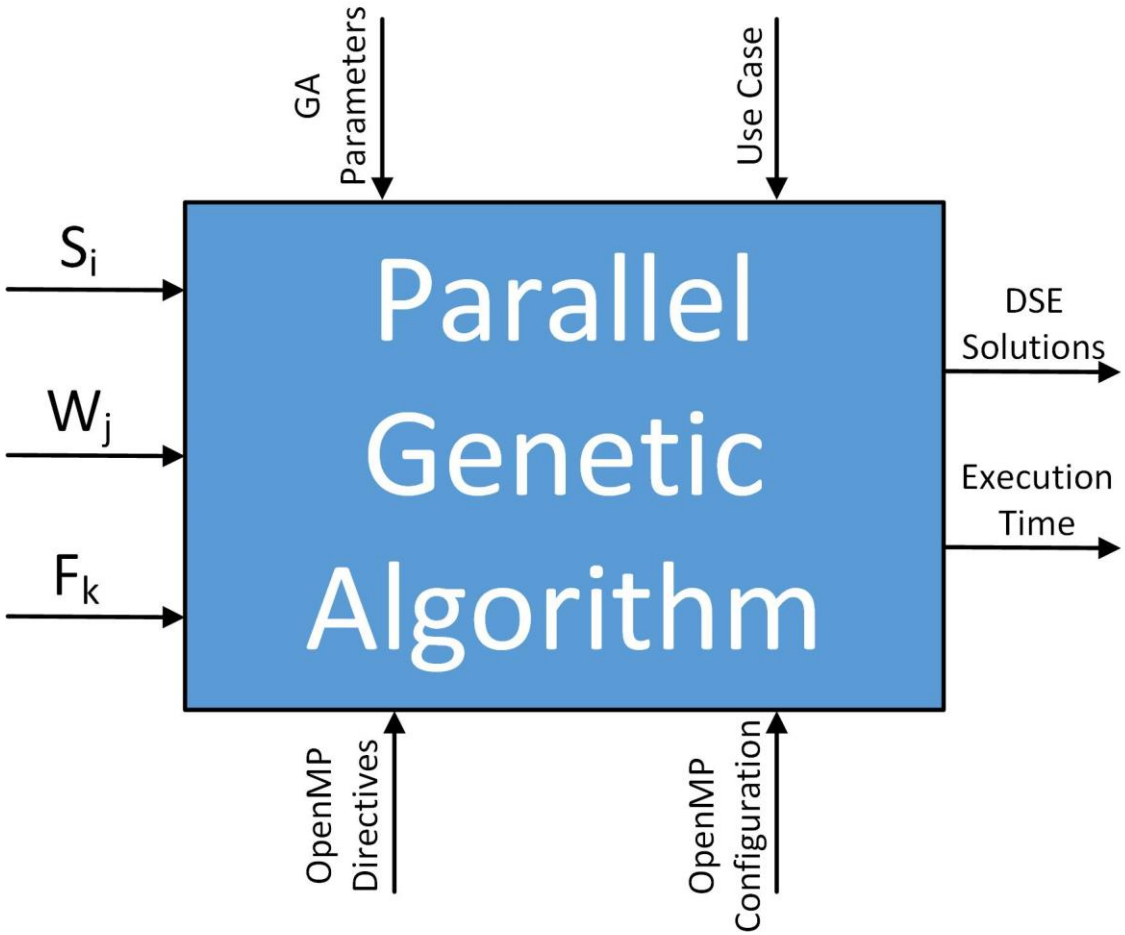
Methodology and Scenarios

INPUT:

- **S_i:** sub-population size
- **W_j:** number of workers/threads considered
- **F_k:** number of objective functions evaluated in parallel
- **GA Parameters:** mutation, crossover, selection, etc.
- **Use Cases**
- **OpenMP Directive**
- **OpenMP Configuration**

OUTPUT:

- **DSE solutions**
- **Execution Time**



Methodology and Scenarios

Different tests and configurations:

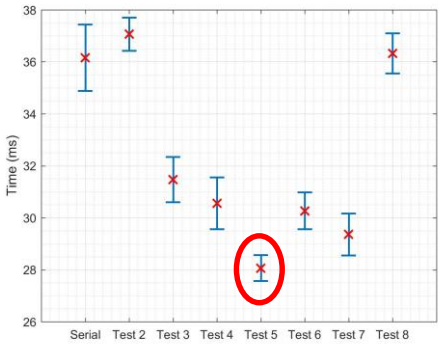
1. Serial;
2. Type 1 with parallel evaluation of objective functions for each individuals with 2 threads;
3. Type 2 with parallel evaluation of utility function using subpopulation sets and the *omp parallel for* with 2 threads;
4. Type 2 with parallel evaluation of utility function using subpopulation sets and the *omp parallel for* with 4 threads;
5. Type 2 with parallel evaluation of utility function using sub-population sets and the *omp parallel for* with 2 threads, schedule guided;
6. Type 2 with parallel evaluation of utility function using subpopulation sets and *omp parallel sections* with 2 sections and 2 threads;
7. Type 2 with parallel evaluation of utility function using subpopulation sets and omp parallel sections with 4 sections and 4 threads;
8. Type 3 (i.e., hybrid approach) with parallel evaluation of objective functions using sub-population and omp parallel sections with 2 parallel flows and 2 sections

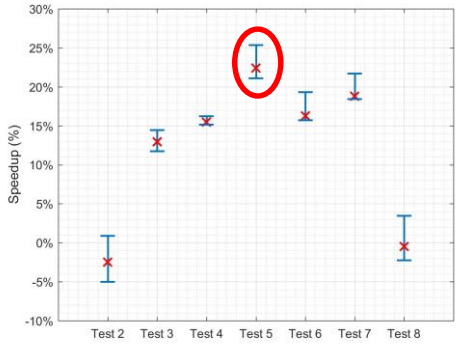
6. Experimental Results

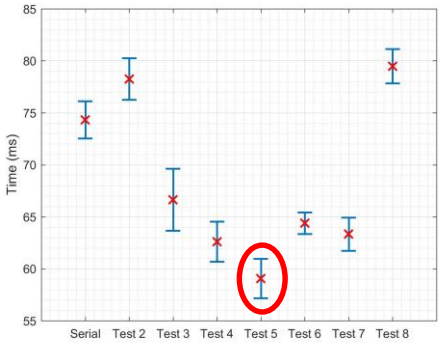
Experimental Results

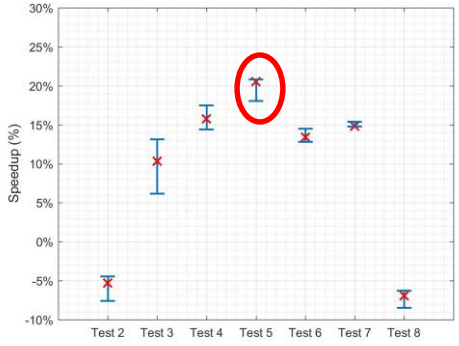
Parallelism performance table

	500000 individuals				1000000 individuals			
Impl.	Best Case (s)	Speed-up	Worst Case (s)	Speed-up	Best Case (s)	Speed-up	Worst Case (s)	Speed-up
1.	34	-	38	-	71.5	-	76.5	-
2.	36	-5.56%	38	0	74.7	-4.28%	82.3	-7.05%
3.	30,1	11,47%	32,6	14,21%	62,1	13,15%	71,8	6,14%
4.	29	14,7%	32	15,79%	59	17,48%	65,5	14,38%
5.	27,4	19,41%	29	23,68%	57	20,28%	62,7	18,03%
6.	29,5	13,23%	31,6	16,84%	62,7	12,31%	65,8	13,99%
7.	28,6	15,88%	31	18,42%	60,5	15,38%	65,2	14,77%
8.	35,5	-4,22%	37,5	1,32%	76	-5,92%	83	-7,83%









7.
Conclusion and Future Work

Conclusion and Future Work

- This work has presented a DSE approach extended to implement a parallel genetic algorithm able to reduce execution time while it does not degrade the goodness of the final DSE solution founded
- An approach to finding the best PGA configuration is presented, where the designer can changes input parameters to achieve desired performances
- Results show the need to do not fix the PGA configuration using OpenMP, while the performances depend on population size and GA configuration
- FUTURE WORKS:
  - Exploit PGA on different technologies and parallel programming languages (GPU/CUDA, multi/many cores/OpenMPI, etc..)
  - Try to implement also fine-grained or coarse-grained PGA
  - Switch from an offline DSE to a runtime DSE able to self-adapt the system respect to several constraints (performance, power/energy, area, etc.)

Thanks!

Questions?