Optimizing simulations by exploring design space with CORHPEX

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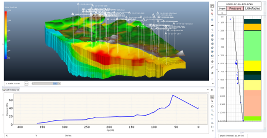
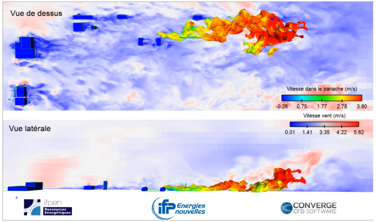
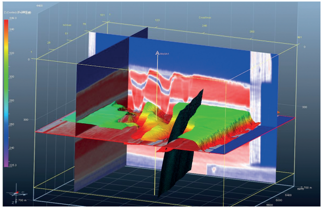
supervised by Ani Anciaux-Sedrakian, Thomas Guignon, Olivier Aumage, and Mihail Popov

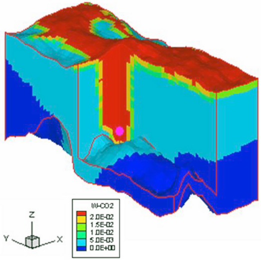
IFPEN, R11 - Inria STORM

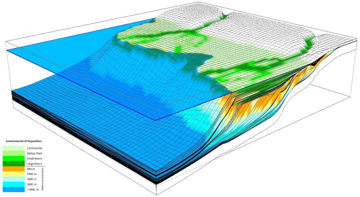
Simulators

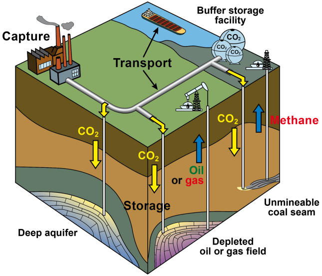

Pressure
Lithofacies


Vue de dessus
Vitesse dans le panache (m/s)
-0.26 0.75 1.77 2.78 3.80
Vitesse vent (m/s)
0.01 1.41 3.35 4.22 5.62
Vue latérale
ifpen Ressources Energétiques
ifp Energies nouvelles
CONVERGE CFD SOFTWARE




W-CO2
2.0E-02
1.5E-02
1.0E-02
5.0E-03
0.0E+00
Z
Y
X


Environments of Deposition


Capture
Buffer storage facility
Transport
CO_2
CO_2
CO_2
Methane
Oil
or gas
Storage
Unmineable coal seam
Deep aquifer
Depleted oil or gas field

Complex systems

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- Number of threads
- Memory hierarchy : memory, L3, L2, L1
- Non-Uniform Memory Access (NUMA) effects
- Simultaneous Multithreading (SMT)
- Thread placement (binding policy)
- Prefetchers (may require root privileges)
- Frequency (may require root privileges)
- Instruction set
- Accuracy (simple or double precision, compliance with IEEE standard)
- Compiler optimizations

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Values can improve or reduce execution time and/or energy consumption.
Parameters influence each other.

Impact on simulator codes

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There is no recipe to get the best performance and energy consumption on every machine for every application.

A framework for optimization space exploration: CORHPEX

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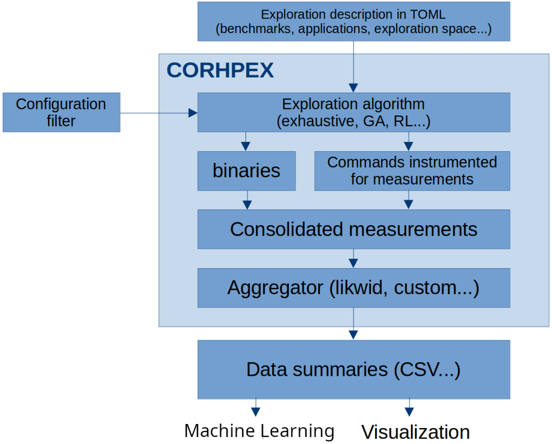

Target and constraints

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Optimization target

- Time (performance)
- Energy (energy savings)
- EDP (time x energy)

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Constraints

- Accuracy (simple, double, mixed precision)
- Micro-architecture (the machine used for the execution)

The space

Dimension	Sub-dimension	Options	Size
Number of threads*		1,4,8,16,32,64	6
Thread binding	package	First,Last	2
	die	First,Last	2
	L3	First,Last	2
	smt	First,Last	2
Prefetchers	DCU IP-correlated	On,Off	2
	DCU	On,Off	2
	L2 Adj. Cache Line	On,Off	2
	L2 Streamer	On,Off	2
Compiler flags	Optimization flags	-O2,-O3, -O3 without vectorization	3
	Vecto cost model	very cheap, cheap, dynamic	3
	fast-maths	On, Off	2
	Instruction set*	-msse4,-mavx2,-march=native	3
Precision†	Storage	float, double	2
	Computing	float, double	2

The space

Dimension	Sub-dimension	Size	IFPEN	[1]	[2]	[3]
Number of threads*		6	X		X	X
Thread binding	package	2		partial with data mapping	partial with data mapping	partial with data mapping
	die	2				
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1 M. Diener et. al. "Characterizing communication and page usage of parallel applications for thread and data mapping," 2015, doi: 10.1016/j.peva.2015.03.001.

2 M. Popov et. al., "Efficient thread/page/parallelism autotuning for numa systems," 2019, doi: 10.1145/3330345.3330376.

3 I. Sánchez Barrera et. al., "Modeling and optimizing numa effects and prefetching with machine learning," 2020. doi: 10.1145/3392717.3392765.

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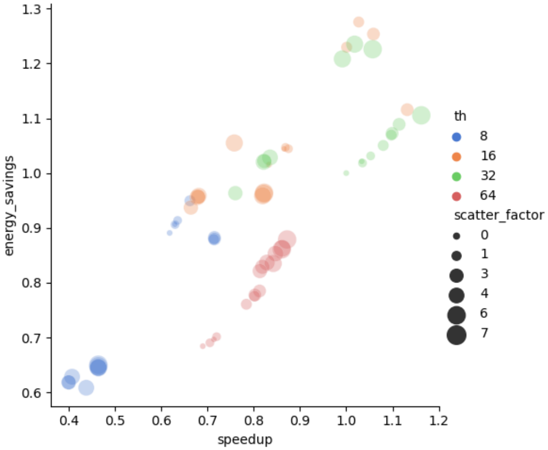
Experimental results: small exhaustive exploration



- CapillaryPressureLaw
- AMD EPYC 7301 (Zen), 2 CPUs, 16 cores/CPU (Grid5000)
- Space
  - Number of threads
  - Binding policy

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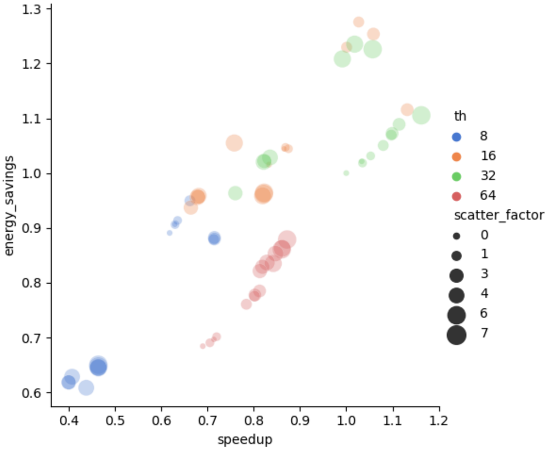

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4 configurations in Pareto set:

- 3 with 16 th on 1 CPU,
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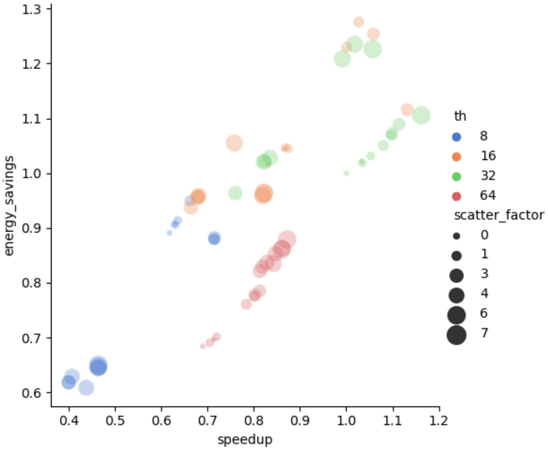

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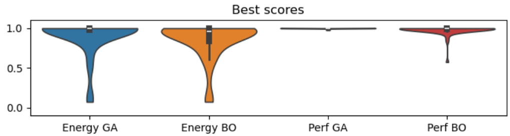
Need to cooptimize the 2 dimensions.

Experimental results: optimization algorithms

- NAS Parallel benchmark, Rodinia, PARSEC benchmark, LULESH, CLOMP
- Intel Xeon Gold 6130 (Skylake)
- Space
  - Number of threads
  - Binding policy
  - Page mapping
  - Prefetchers
  - Multithreading
- Algorithms
  - Genetic Algorithm
  - Bayesian Optimization

Experimental results: optimization algorithms



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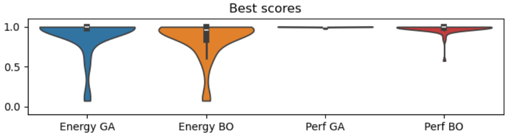

Performance easier to optimize than energy.

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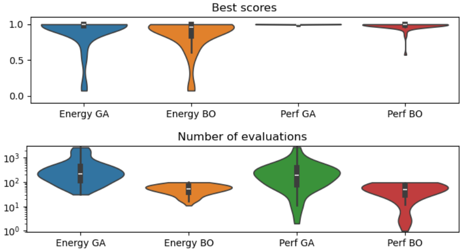

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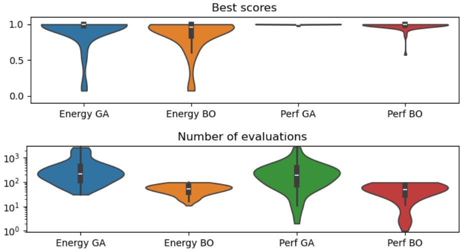

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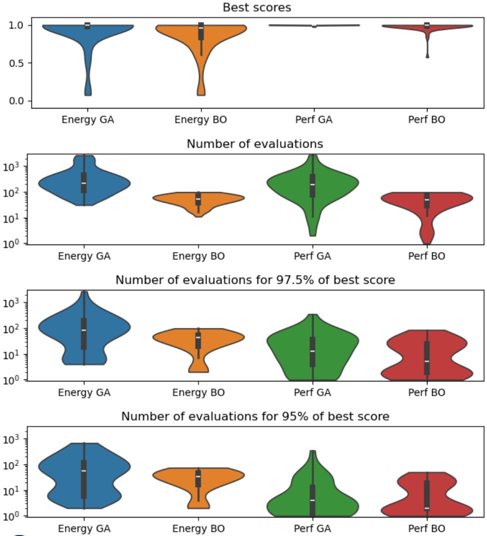

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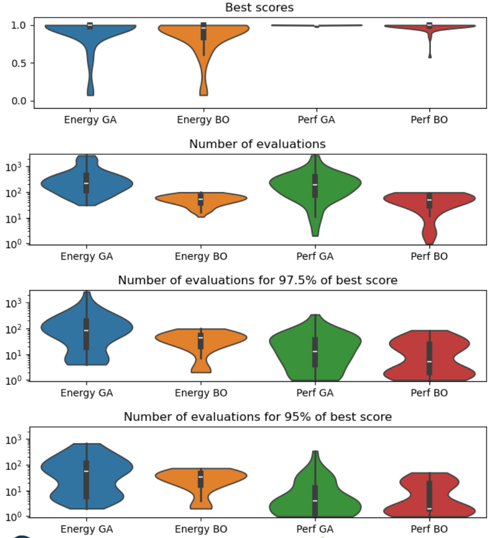

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Achieving 97.5% or 95% of optimal score is faster.

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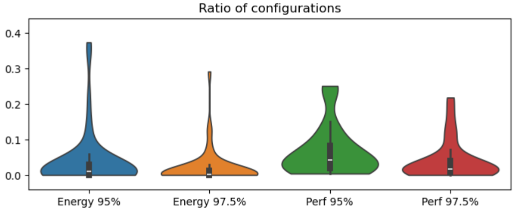
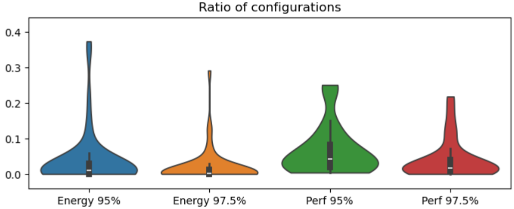


For most codes less than 5% of the configurations achieve at least 95% of the gains.

Experimental results: optimization algorithms



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Less configurations achieve it for energy than for time.

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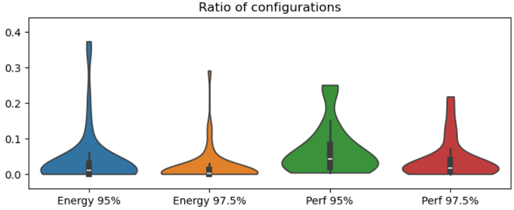

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It is difficult.

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- Why ?
  - faster than execution

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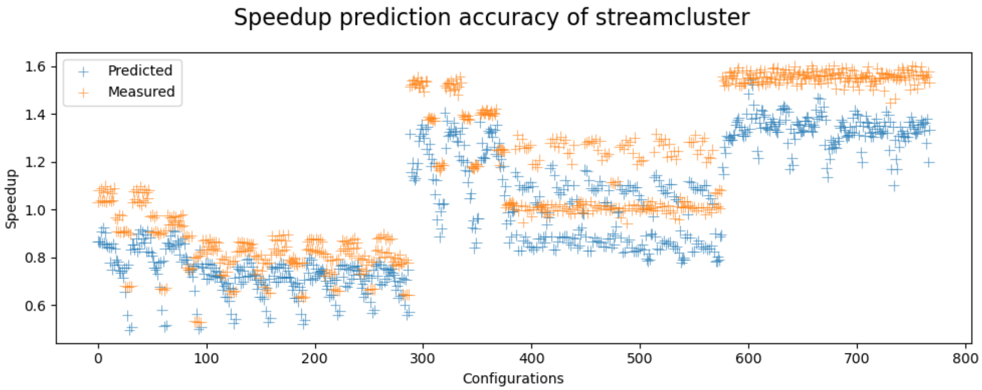

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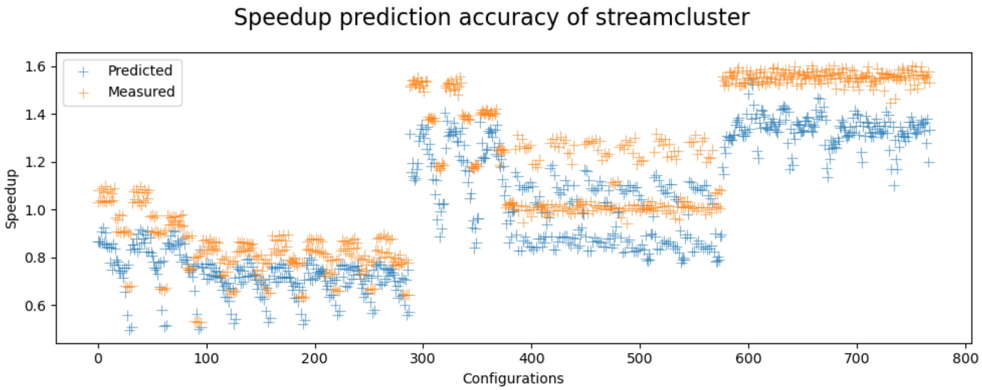

Predictions are usually below the measures but trend is captured with 9% of the space explored.

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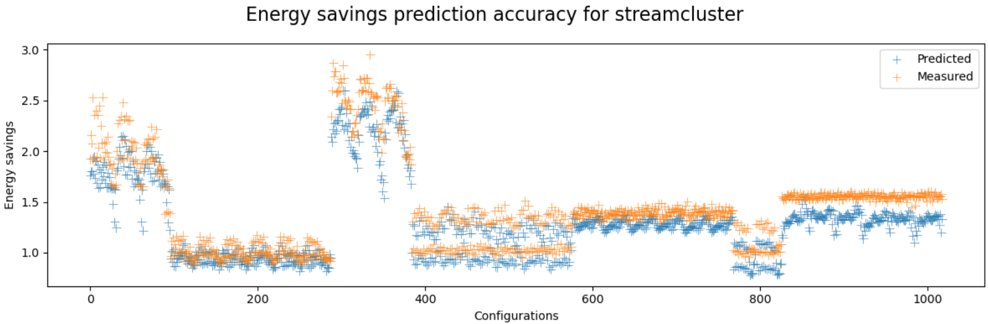

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