

HIGH PERFORMANCE COMPUTING: TOWARDS BETTER PERFORMANCE PREDICTIONS AND EXPERIMENTS

Tom Cornebize

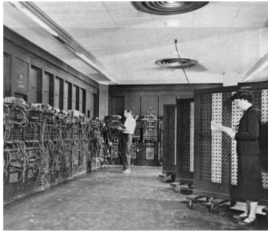
2 June 2021, PhD defense



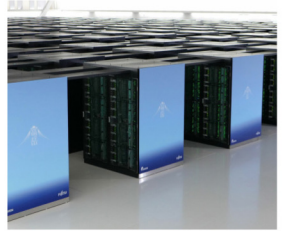
NO SCIENCE WITHOUT COMPUTING



Arithmomètre (1851)



ENIAC (1945)



Fugaku (2021)

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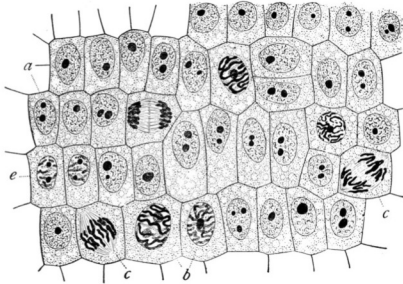


Fugaku (2021)

Last decades:

- Exponential **performance** improvements (e.g. sequencing an entire human genome costed \$100,000,000 in 2001, \$1000 now)
- At the price of **complexity** (both software and hardware)

EXPERIMENTAL STUDY OF COMPUTER PERFORMANCE



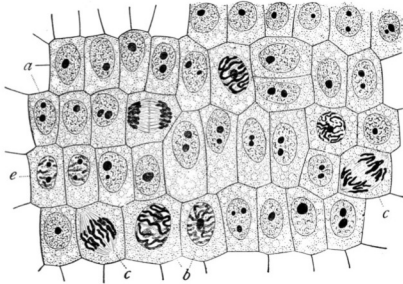
Similar to natural sciences

Complexity \Rightarrow Variability and Opacity

\Rightarrow No perfect model

\Rightarrow Need for **experiments**

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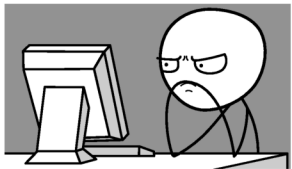
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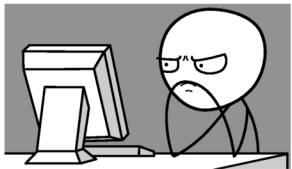
Empirical studies can be carried in **reality** or in **simulation**

Typical Performance Evaluation Questions (Given my application and a supercomputer)



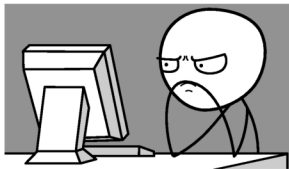
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 - How many nodes?
 - For how long?
 - Which parameters?

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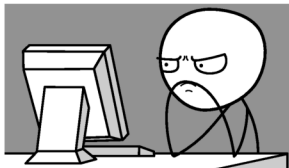
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Holy Grail: Predictive Simulation on a “Laptop”

Capture the **whole application** and **platform complexity**

Initial goal: **predict** the performance of
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Thesis contributions (towards this goal)

- Case study: High Performance Linpack (HPL)
- Extensive (in)validation, comparing simulations with reality
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- Experiment methodology, to bias or not to bias
- Performance tests, to detect eventual platform changes

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PERFORMANCE PREDICTION THROUGH SIMULATION

SIM(EM)ULATION: THE SMPI APPROACH



Full reimplementation of MPI on top of 

- C/C++/F77/F90 codes run **unmodified out of the box**
- Simply replace mpicc/mpirun by smpicc/smpirun



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Emulation: how?

- Application runs for real on a laptop
- Communications are faked, good fluid network models
- **Performance model** for the target platform

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Contribution: Skip the expensive computations (mostly **dgemm**) and replace them by performance models

QUICK WORD ON HPL

Validations of SMPI before this thesis: simple applications without any high performance tricks

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Contribution: predict accurately the performance of HPL

- Computations and communication overlap (custom collectives)
- More representative of some HPC applications
- Well established, used for the Top500



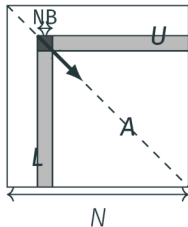
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Allocate and initialize A
for $k = N$ **to** 0 **step** NB **do**
 Allocate the panel
 Factor the panel
 Broadcast the panel
 Update the sub-matrix

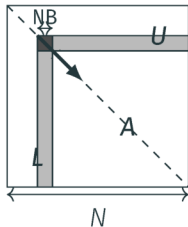
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Tuning parameters

- Process grid
- Block size
- Broadcast algorithm
- etc.

Hundreds of combinations

MODELING COMPUTATIONS

$$\text{dgemm}(M, N, K) = \alpha \cdot M \cdot N \cdot K$$



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