

## Int  ration Logiciel Architecture

Les performances et leur mesure

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Motivation Why How  
 Metrics How Many ?

## Metrics How Many ?

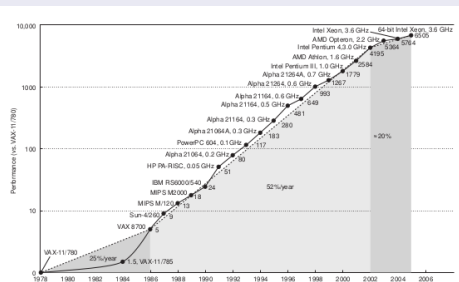
### How many

- Computer you own ?
- Processor you own ?
- Computer you use ?
- Computing power ?

Motivation Why How  
 Metrics Moore

## Metrics Moore

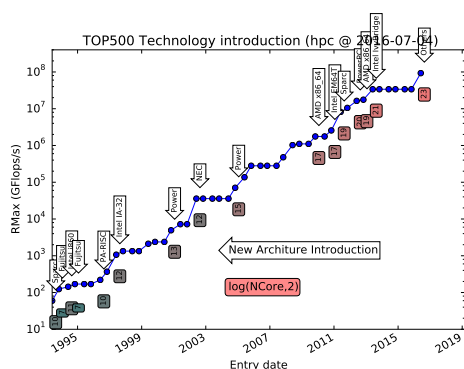
### La loi de Moore



Growth in processor performance since the mid-1980s. This chart plots performance relative to the VAX 11/780 as measured by the SPECint benchmarks [Hennessy]

Motivation Why How  
 Metrics Top500

## Metrics Top500



Lien entre l'introduction d'une nouvelle technologie et son impact sur les performances

Motivation ○○●○○○○○○○○	Why ○○○○○○○○○○○○	How ○○○○○○○○○○○○○○
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## Motivation

### Why

#### How

# Metrics How to Measure Performance ?

### What scale ?

- Application level (TPS, Frame/s, .../)
- Run to completion
- Method level
- Instruction level

### Tools

- Wall clock
- gettimeofday
- Performance counters

### Full application or function call ?

- Cold start / warmup
- Statistic / multiple calls
- How many calls

## Motivation

### Why

#### How

# Vocabulaire : Cycle par seconds / Flops

### Units

- Mips** Million operation per second
- Flops** Floating point operation per second  
<http://www.top500.org>
- Flops/Watt** Floating point operation per watt per second  
<http://www.green500.org>
- IPC** : Instructions per Cycle

### How to mesure

- Analytique (wall clock)
- Instrumentation
  - "Portable" (gettimeofday())
  - Hardware (hardware performance counter)

## Motivation

### Why

#### How

# Vocabulaire Peak / Sustained

### Notions

- Peak** performance : maximal theoretical performance, assuming no bubble
- Sustain** performance : real acheived performance, on a real benchmark

### Cost

- What is the percentage you're ready to lose ? 90% 95% ?
- How many are you ready to pay (time, money) to minimise this loss ?

<http://www.top500.org>

## Vocabulaire Lois

### Obeys the law!

- Moore [http://en.wikipedia.org/wiki/Moore's\\_law](http://en.wikipedia.org/wiki/Moore's_law)
- Amdahl [http://en.wikipedia.org/wiki/Amdahl's\\_law](http://en.wikipedia.org/wiki/Amdahl's_law)
- Memory bound [http://en.wikipedia.org/wiki/I/O\\_bound](http://en.wikipedia.org/wiki/I/O_bound)
- CPU bound [http://en.wikipedia.org/wiki/CPU\\_bound](http://en.wikipedia.org/wiki/CPU_bound)

## Vocabulaire Speedup

### Notion

Speedup  $S = 100 * \frac{T_{seq}}{T_{opt}}$   
 Can be between

- 1 and N processor
- 1 and vectorized
- non optimized versus optimized version

Mesure Quality what are the execution conditions : data set, computer workload, reproducibly, ...

Computer science has to use "human science" tools & methodology

## Amdahl2

### Argumentation

Assume that a task has two independent parts, A and B. B takes roughly 25% of the time of the whole computation. By working very hard, one may be able to make this part 5 times faster, but this only reduces the time for the whole computation by a little. In contrast, one may need to perform less work to make part A be twice as fast. This will make the computation much faster than by optimizing part B, even though B's speed-up is greater by ratio, (5x versus 2x)

### Illustration

Two independent parts A B

Original process

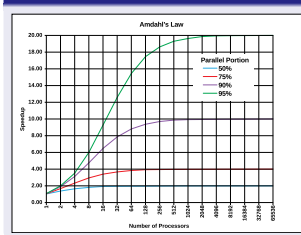
Make B 5x faster

## Vocabulaire Amdahl

### Argumentation

The speedup of a program using multiple processors in parallel computing is limited by the sequential fraction of the program. For example, if 95% of the program can be parallelized, the theoretical maximum speedup using parallel computing would be 20x as shown in the diagram, no matter how many processors are used.

### Illustration



Motivation

Why

How

Metrics Roofline model

Metrics Roofline model

Intensité arithmétique

(From <https://crd.lbl.gov/departments/computer-science/PAR/research/roofline/>)

Motivation

Why

How

Metrics Roofline

Metrics Roofline

Arithmetic intensity versus performance

[https://en.wikipedia.org/wiki/Roofline\\_model](https://en.wikipedia.org/wiki/Roofline_model)

Motivation

Why

How

How : Outillage

How : Outillage

Outillage pour la performance

- HW related
  - gprof
  - gdb
- Simulation
  - Performance counters
  - JTAG
- Analytical
  - Statical analysis

Motivation

Why

How

How : Static Compilation chain

How : Static Compilation chain

Static compilation (on C language) :

- 1 Preprocessor (all # stuff : rewriting) `cc -E`
- 2 Compilation (from C to textual assembly) `cc -S`
- 3 Assembly (from textual asm to binary asm) `cc -c`
- 4 Executable (binary + dynamic library)

Optional

- Profiling : Compile (use `-pg`) produce File ; Run File ; Use `gprof`
- `cc -da` dump all intermediate representation

(Use `gcc -v` to see all the steps)

Don't stop at static time (Operating system + processor) : Load in memory, dynamic linking ; Branch resolution ; Cache warmup

#### Argumentation

- Compile using -pg option  
gcc -pg -o prog prog.c, add information at the begin / end of each function
- Run the code ./prog (create the gmon.out file)
- Run gprof gprof prog
- Read report !

#### Pitfalls

- Warning with -O3 interaction !
- Use -O0 as first pass
- Use -O3 for real

#### Limitations

- Not fine grain
- Measure perturbation

#### Performance counter from HW

- Simple one : cycle counter
- More complex : RAT\_STALLS  
Counts the number of cycles during which execution stalled due to several reason
- L2, L3 cache access, hit, miss ...
- Miss prediction, etc

#### Tools

- Intel tools : <http://www.intel.com/software/pcm>
- Papi : <http://icl.cs.utk.edu/papi>
- Tiptop from Inria : <http://tiptop.gforge.inria.fr/>

#### Limitations

- Complicated to understand / analyse
- No real portable library

#### Question

- Comment calcule-t-on l'IPC ?

https:

[//en.wikipedia.org/wiki/Hardware\\_performance\\_counter](https://en.wikipedia.org/wiki/Hardware_performance_counter)

#### Description

- Hardware connector
- Able to get processor internal information
- Embedded domain

#### Drawback

- Need HW access
- Impossible to get large configuration



#### How

- Emulate a new architecture
- Configuration via Hardware Description Language
- Programming via compiler for the emulated architecture
- :

Link FPGA

#### Allow

- Emulate fonctionnaly a new architecture

#### Attention

- Run at low frequency
- Does not have probes

## Hardware emulator

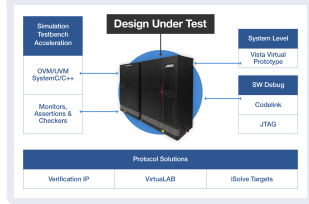
### FPGA based

- Similar to FPGA
- Emulate a new architecture
- Support for HW debug (without latency)

### But

- But slow freq.

### Veloce emulator



## How : gdb

### Debugger

- Source level debugger
- Compile with -g (gcc -g -o p.p.c)
- Use gdb program (or ddd or emacs or ...)
- Step execution : next, previous line, next, previous insn
- Inspect live data
- Set breakpoint, on line, on insn, on data access

### Other usage

- .gdbinit : automatize test
- Embed python into gdb : program information collection

### Question

- Why -O3 could perturb gdb ?
- How could gdb stop an execution ?

## How : qemu

### Qemu

- Instruction level simulator
- Emulate processor and peripheral
- Modes System & User

### Usage

- Functional simulation
- Trace information

<http://qemu.org>

## How : CrossCompiler

### What

- Allow to generate binary code for a machine A on a machine B
- How to build ?
- 

### Limitation

- crosstool-ng, buildroot
- llvm
- FreeBSD, NetBSD

## How : Stats

## Are execution reproducible ?

- Reproducibility !
- Why ?

## Methodology

- Statistical approach
- Best run, multiples run (how many)
- Extrema elimination
- Means
- Cold start, warmnup