Intéraction Logiciel Architecture

Les performances et leur mesure

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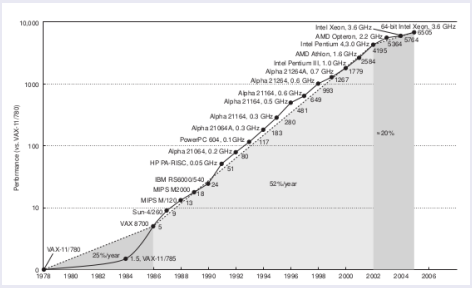
Metrics How Many ?

How many

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

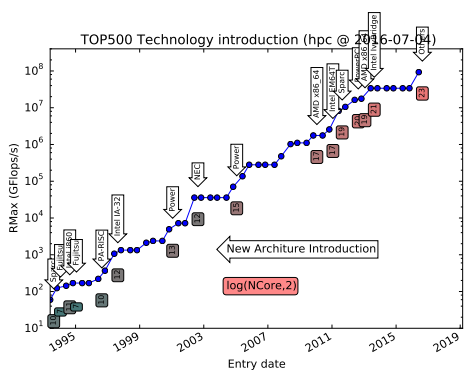
Metrics Moore

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]

Metrics Top500



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

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

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)

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

Obey the law !

- Moore `http://en.wikipedia.org/wiki/Moore's_law`
- Amdahl `http://en.wikipedia.org/wiki/Amdahl's_law`
- Memory bound `http://en.wikipedia.org/wiki/IO_bound`
- 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)

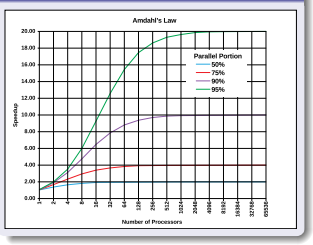
Illustration

Vocabulaire Amdahl

Argumentation

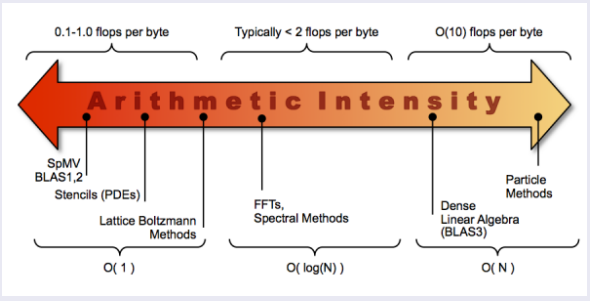
The speedup of a program using multiple processors in parallel computing is limited by the sequential fraction of the program. For example, if 95% of the program can be parallelized, the theoretical maximum speedup using parallel computing would be 20x as shown in the diagram, no matter how many processors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

Illustration



Metrics Roofline model

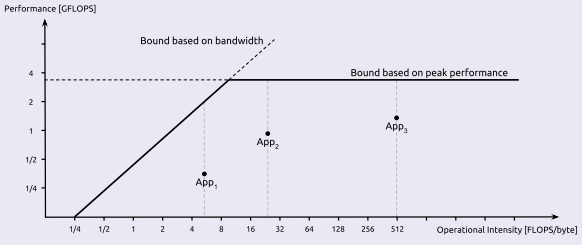
Intensité arthmétique



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

Metrics Roofline

Arithmetic intensity versus performance



`https://en.wikipedia.org/wiki/Roofline_model`

How : Outillage

Outillage pour la performance

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

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

How : gprof

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

How : PerfCounter

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`

How : JTAG

Description

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

Drawback

- Need HW access
- Impossible to get large configuration

FPGA : Field Programmable Gate Array

How

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

Link FPGA

Allow

- Emulate functionnaly a new architecture

Attention

- Run at low frequency
- Does not have probes

Hardware emulator

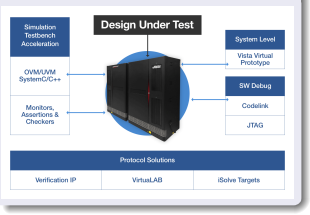
FPGA based

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

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 peripherical
- Modes System & User

`http://qemu.org`

Usage

- Functional simulation
- Trace information

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 reproductible ?

- Reproductibility !
- Why ?

Methodology

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