Performance Engineering

Parallel Performance

Elisabet Molin, Xavi Aguilar

elimo@pdc.kth.se

PDC

KTH, Sweden

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Why Parallel Performance?

- Reduce calculation time

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Why Parallel Performance?

- Reduce calculation time
- Expand to solve new problems

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Why Parallel Performance?

- Reduce calculation time
- Expand to solve new problems
- Choosing appropriate computers

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Characteristics of a code

- Communication pattern

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Characteristics of a code

- Communication pattern
- Load balance

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- Communication pattern
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- Number of individual computations

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- Memory usage

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Characteristics of a code

- Communication pattern
- Load balance
- Number of individual computations
- Memory usage
- Data I/O pattern
- Size and layout of data sets

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Know your enemy

What is expensive and slow?

- Data transfer

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Know your enemy

What is expensive and slow?

- Data transfer
- File I/O
- Bad memory utilization
- Serial code sections (Amdahl's law)

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Where to optimize

- Premature optimization is the root of all evil

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- 90 % of the time will usually be spent on 10 % of the code

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- 90 % of the time will usually be spent on 10 % of the code
- Won’t reach theoretical peak performance

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Presenting Performance data

To be able to understand a graph the following is required:

- What input data was used? (dense/sparse, size, precision. . .)

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- How many runs were averaged? (error margins)

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- What computer was used? (memory, cpu, interconnect. . .)
- How many nodes were used?
- How many runs were averaged? (error margins)
- What is the base line? (what is the comparison made against)

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Typical graphs

- T_1^S shortest time for *the best serial program*.

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  Absolute $\eta_p = \frac{S_p}{p}$

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  Relative efficiency is a measure of *scalability*

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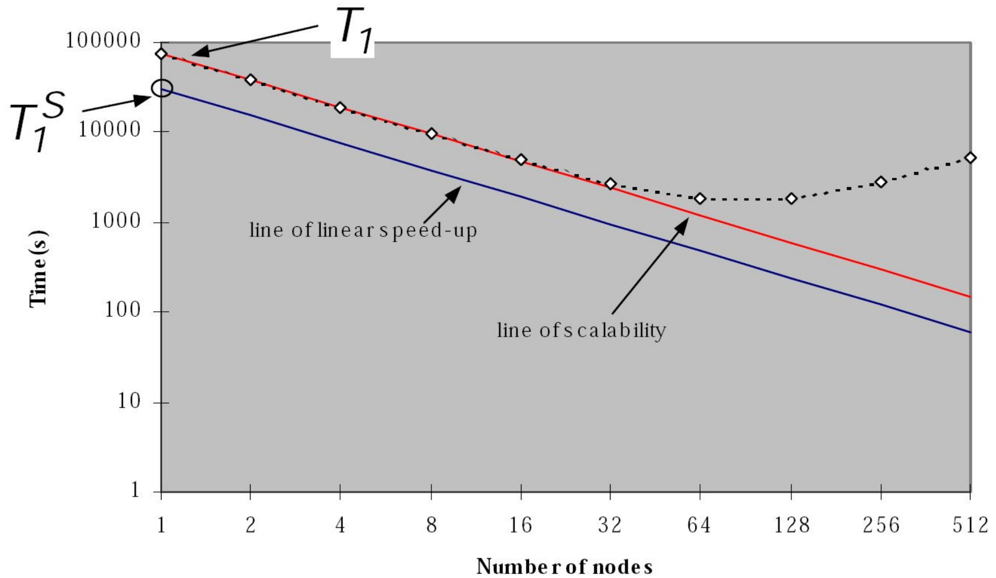
Execution time



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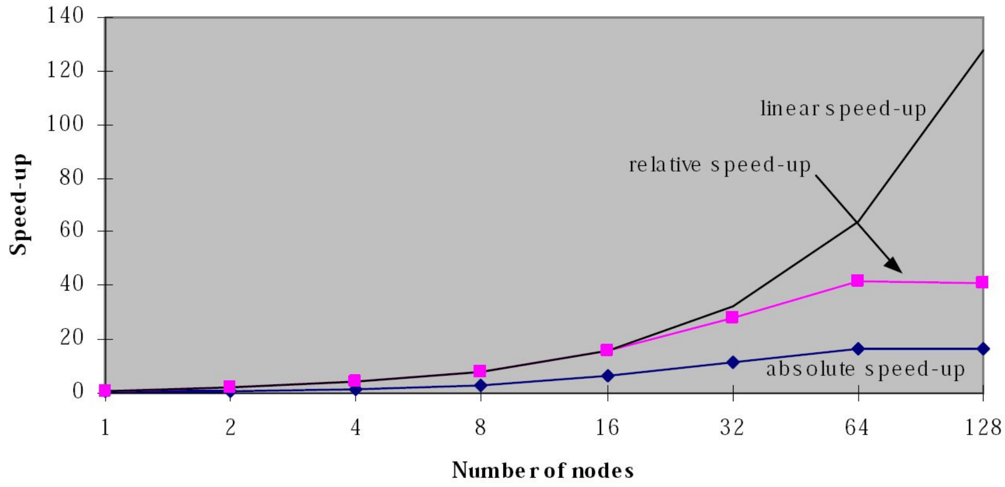
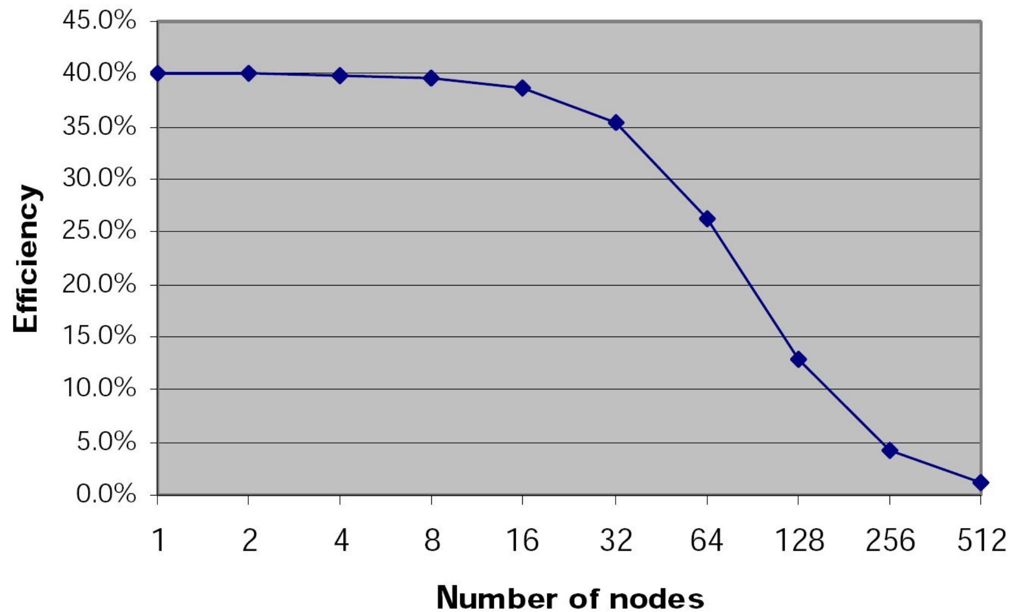
Speed-up



Absolute $S_p = \frac{T_1^S}{T_p}$, relative $S_p^{rel} = \frac{T_1}{T_p}$

Efficiency



$$\eta_p^{rel} = \frac{S_p^{rel}}{p} = \frac{\frac{T_1}{T_p}}{p}$$

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Where to start

Performance improvement doesn't always require changing your code.

- Compiler optimization flags

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- Communicate according to network topology

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- Communicate according to network topology
- Place data according to network topology

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Measuring Performance

A. External timers

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Measuring Performance

A. External timers

B. Internal time

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Measuring Performance

A. External timers

B. Internal time

C. Performance counters

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Measuring Performance

A. External timers

B. Internal time

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D. Profilers

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Measuring Performance

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E. Call Tracing

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A. External timers

- Measuring wall clock time on executable

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- `/usr/bin/time`

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! Multithreaded execution (on one node)

$$T = t_i^{last} - t_0^{first}$$

t_0^{first} — first thread starts execution t_i^{last} — last thread finishes.

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B. Internal Timers

- Source code adapted to start, stop and save timers

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+ A first easy to use and available method to measure time
- Affects the program execution time
- Limited resolution (ms)

C. Performance Counters

- Hardware counters — registers counting events in the processor

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- Registered on *every* CPU

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\- Requires CPU and OS support

\- Usually doesn't say where the problem is

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What do we want to know?

- **Where** does the code spend its time?

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What do we want to know?

- **Where** does the code spend its time?
- Want to know what the program actually does when run with a particular input data

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Execution example

```
init()
while i>0
 calc()
 i − −
done()
```

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Execution example

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init()
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m1:  call init()
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c1:   a=a+b
```

```
d1:   print a
```

```
m1
i1
i2
i3
m2
m3
c1
```

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Execution example

```
init()
while i>0
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 i - -
done()
```

```
m1:  call init()
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m3
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m4
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m4
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m2   m2
m3   m5
c1   d1
m4
```

Too much data

- A $2\,\mathrm{GHz}$ processor running for $10\,\mathrm{s}$

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Too much data

- A $2\,\mathrm{GHz}$ processor running for $10\,\mathrm{s}$
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- A $2\,\mathrm{GHz}$ processor running for $10\,\mathrm{s}$
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- Total data generated — $2 * 10 * 4 = 80\,\mathrm{GB}$!

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- Total data generated — $2 * 10 * 4 = 80\,\mathrm{GB}$!
- The data input will affect how your program runs
- Code length will always be $\ll$ number of instructions executed!
- Need a way of reducing data and still get the information!

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D. Profilers

- Two types: **Statistical and Event based profilers**

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- Measuring profiles affects performance
- Still a lot of data saved

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E. Call Tracing

- Call Tracing — Library specific profiling (for example MPI)

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- Records **when** a function was called and **with what parameters**
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\+ Gives you library specific information — which nodes exchanged messages, what was the message size. . .

\- Affects performance (depending on how often library calls are made)

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Performance Tools on Ferlin

Name:	Type:	License:
gprof	statistical profiler	free
papiex	performance counter	free/licensed
mpip	MPI profiling	free
paraver	MPI tracing and profiling	free
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- Single CPU performance is high.

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What is Good Parallel Performance?

- Single CPU performance is high.
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- The network is not the bottleneck.
- Data sent around is at a minimum
- Use Performance Tools to get there!

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