Erlangen Regional Computing Center

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Node-Level Performance Engineering

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Three-day Tutorial

University of Cologne

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http://tiny.cc/NLPE-UCO

High Performance Computing

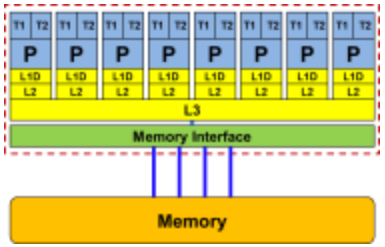
Cycle gymnastics

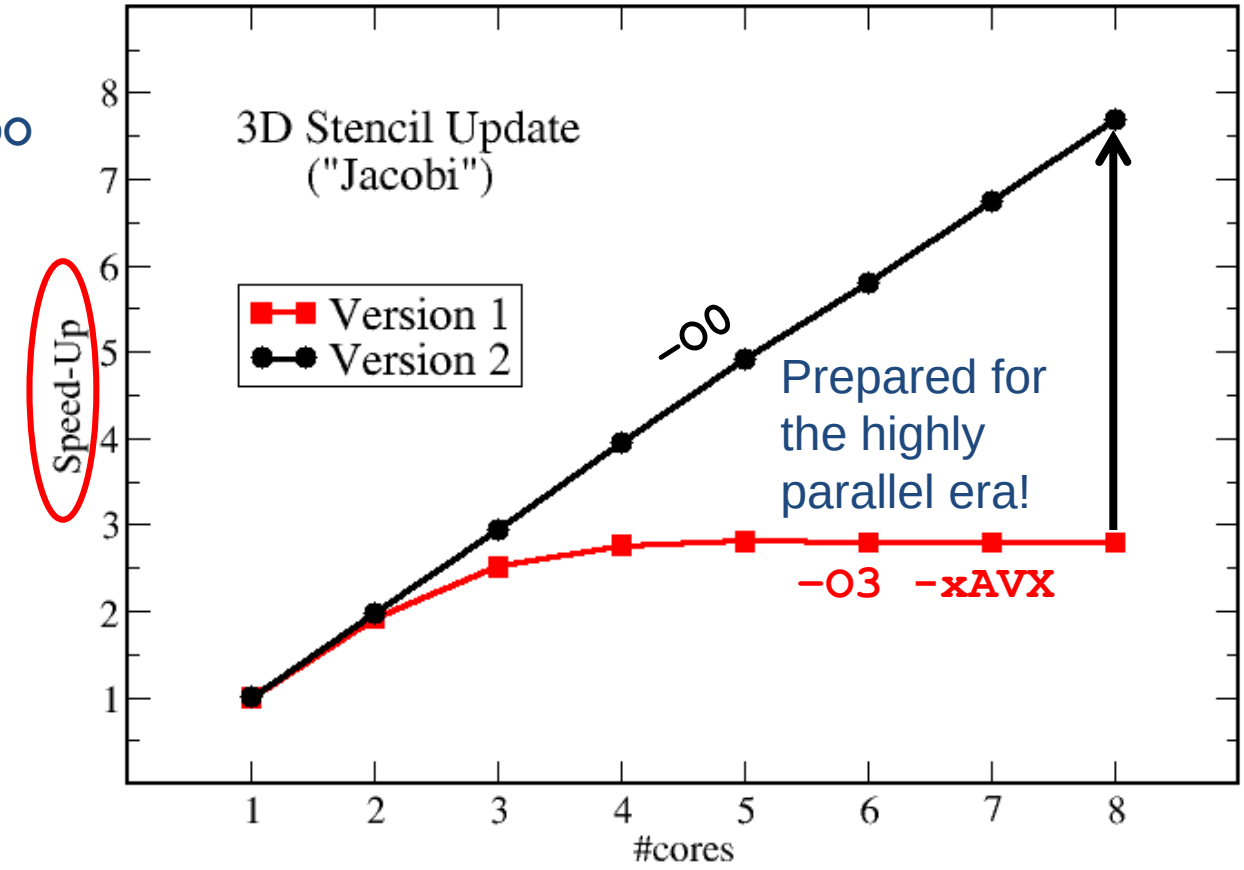
- 1 cycle = smallest unit of time on a CPU (“heartbeat”)
  - Clock speed of typical CPU: 2.4 Gcy/s (or GHz)
- Basic unit of work: Floating-point operation (Flop)
  - Typical peak performance of 20-core CPU: P_{peak} =768 Gflop/s
  - How many Flops per cycle per core is that? $\frac{768 \cdot 10^9 \frac{Flops}{s}}{20\ cores \cdot 2.4 \cdot 10^9 \frac{cy}{s}} = 16\ \frac{Flops}{cy \cdot core}$
  - Typical duration of a double precision multiply: 5 cycles
    - How much time is that? $\frac{5\ cy}{2.4 \cdot 10^9 \frac{cy}{s}} = 2.08 \cdot 10^{-9} s = 2.08\ ns$
- Basic unit of traffic: Byte
- Unit of bandwidth: Bytes/s
  - Typical memory bandwidth: 62 Gbytes/s = $6.2 \cdot 10^{10}$ Bytes/s
  - How many bytes per cycle is that? $\frac{62 \cdot 10^9 \frac{Bytes}{s}}{2.4 \cdot 10^9 \frac{cy}{s}} = 25.8\ \frac{Bytes}{cy}$

Scalability Myth: Code scalability is the key issue

```
!$OMP PARALLEL DO
do k = 1 , Nk
  do j = 1 , Nj; do i = 1 , Ni
     y(i,j,k)= b*(  x(i-1,j,k)+ x(i+1,j,k)+ x(i,j-1,k)+
                    x(i,j+1,k)+ x(i,j,k-1)+ x(i,j,k+1))
    enddo; enddo
enddo
!$OMP END PARALLEL DO
```

Changing only the compile options makes this code scalable on an 8-core chip





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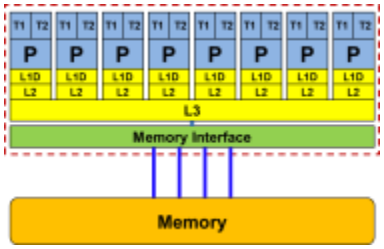
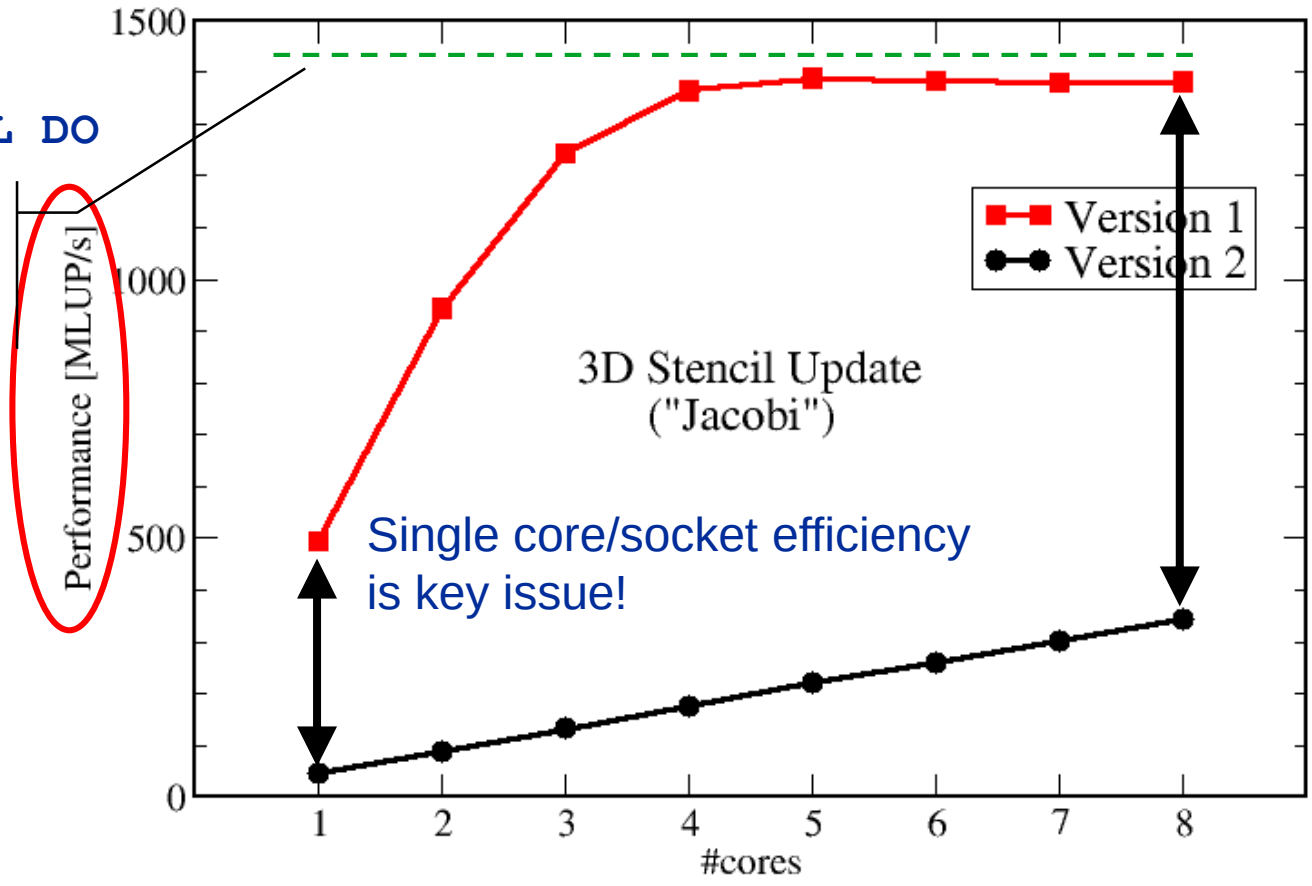
Upper limit from simple performance model:
35 GB/s & 24 Byte/update





A conversation

From a student seminar on “Efficient programming of modern multi- and manycore processors”

Student: I have implemented this algorithm on the GPGPU, and it solves a system with 26546 unknowns in 0.12 seconds, so it is really fast.

Me: What makes you think that 0.12 seconds is fast?

Student: It is fast because my baseline C++ code on the CPU is about 20 times slower.

Questions to ask in high performance computing

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Do I understand the performance behavior of my code?

- What is (or should be) the principal hardware bottleneck (design limit)?
- Does the performance match a model I have made?

What is the optimal performance for my code on a given machine?

- High Performance Computing == Computing at the bottleneck

Can I change my code so that the "optimal performance" gets higher?

- Circumventing/ameliorating the impact of the bottleneck

My model does not work – what's wrong?

- This is the good case, because you learn something
- Performance profiling / microbenchmarking may help clear up the situation

Use your brain! Tools may help, but you do the thinking.