ERLANGEN REGIONAL COMPUTING CENTER

http://tiny.cc/NLPE-PT

Node-Level Performance Engineering

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Cycle gymnastics

http://tiny.cc/NLPE-LRZ

- 1 cycle = smallest unit of time on a CPU (“heartbeat”)
  - Clock speed of typical CPU: 3.0 Gcy/s (or GHz)
- Basic unit of work: Floating-point operation (Flop)
  - Typical peak performance of 8-core CPU: P_{peak} = 192 Gflop/s
  - How many Flops per cycle per core is that? $\frac{192 \cdot 10^9 \frac{Flops}{s}}{8\ cores \cdot 3.0 \cdot 10^9 \frac{cy}{s}} = 8 \frac{Flops}{cy \cdot core}$
  - Typical duration of a double precision multiply: 5 cycles
    - How much time is that? $\frac{5\ cy}{3.0 \cdot 10^9 \frac{cy}{s}} = 1.67 \cdot 10^{-9} s = 1.67\ ns$
- Basic unit of traffic: Byte
- Unit of bandwidth: Bytes/s
  - Typical memory bandwidth: 48 Gbytes/s = $4.8 \cdot 10^{10}$ Bytes/s
  - How many bytes per cycle is that? $\frac{48 \cdot 10^9 \frac{Bytes}{s}}{3.0 \cdot 10^9 \frac{cy}{s}} = 16 \frac{Bytes}{cy}$

PRELUDE:
SCALABILITY 4 THE WIN!

How to ask the right questions

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.

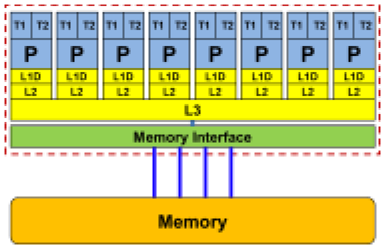
Me: What makes you think that 0.12 seconds is fast?

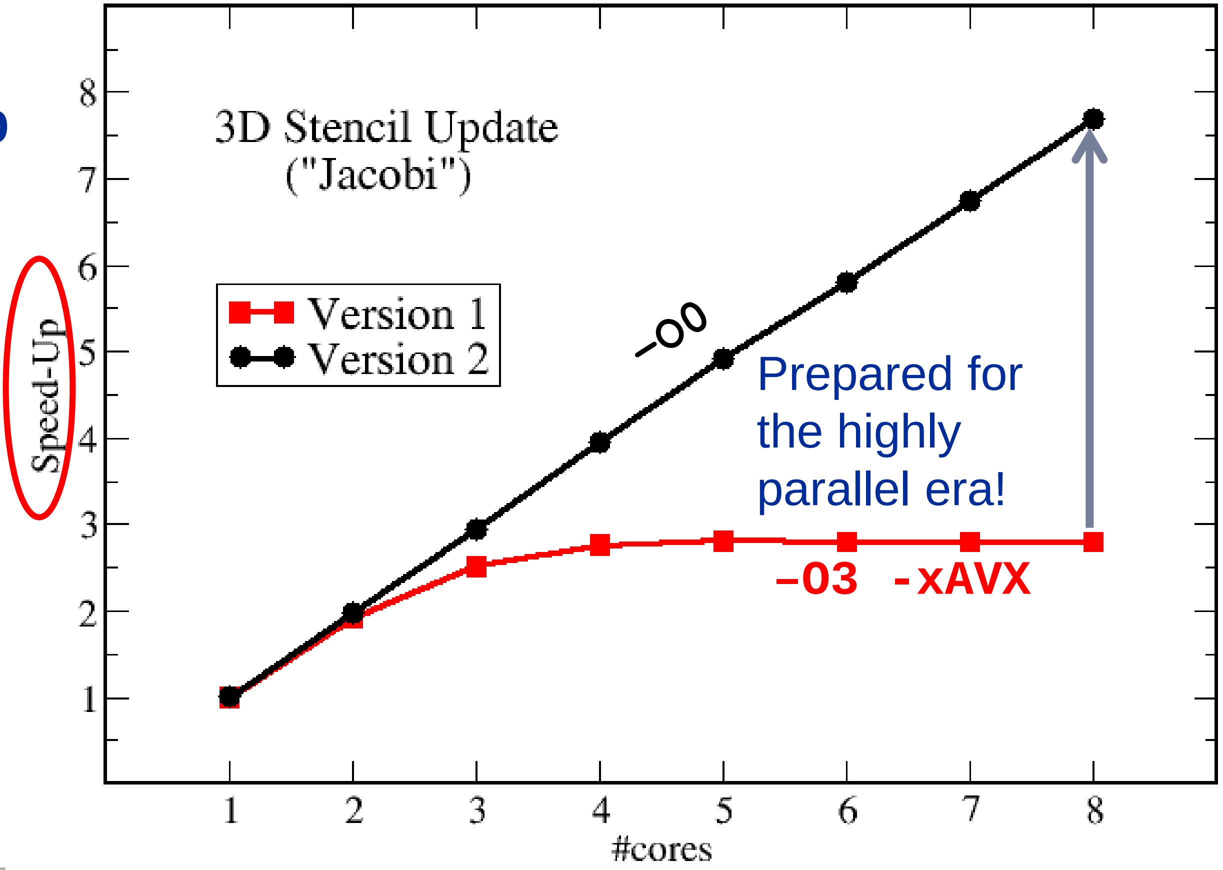
Student: It is fast because my baseline C++ code on the CPU is about 20 times slower.

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





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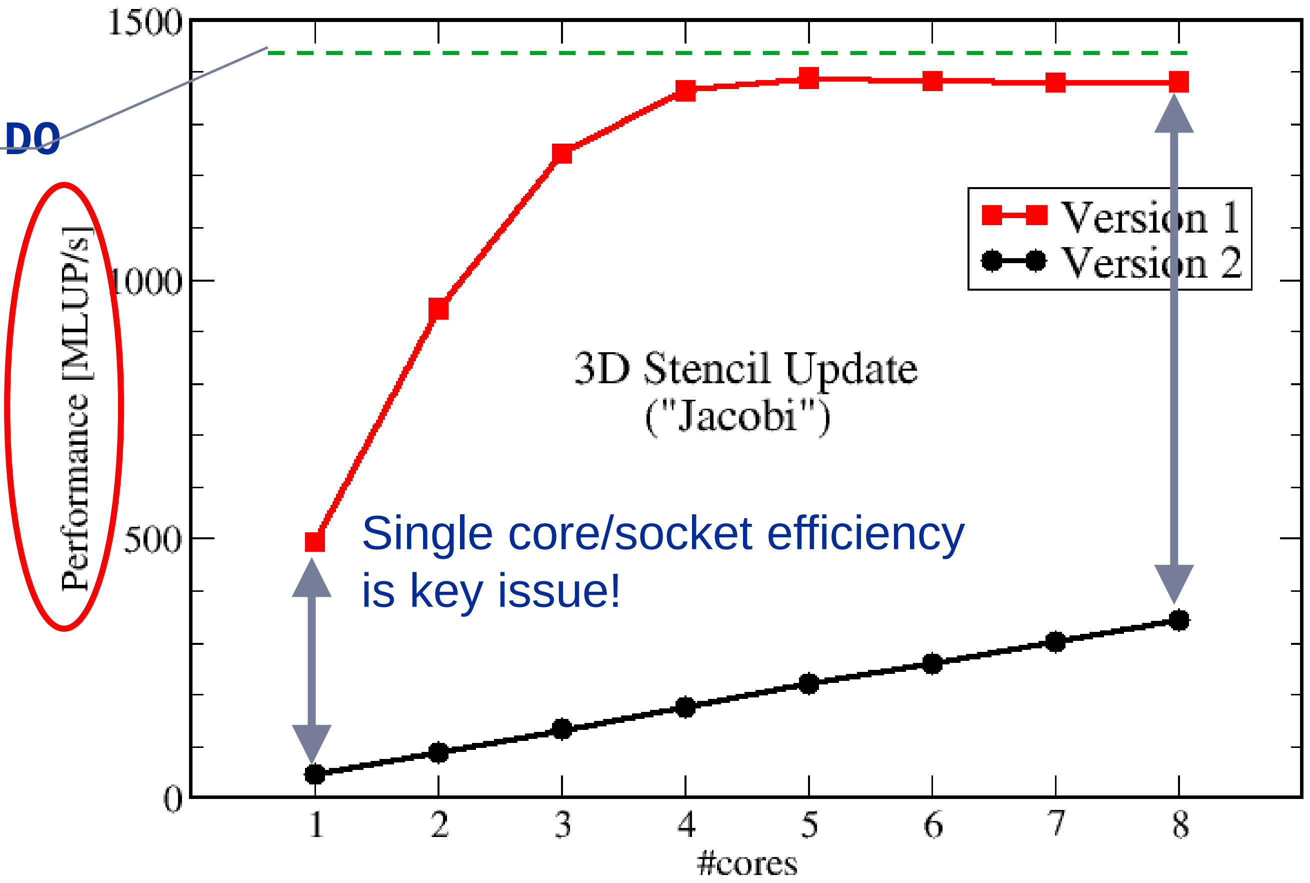
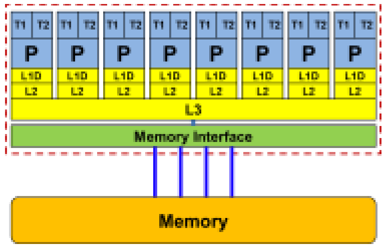
enddo
```

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



Single core/socket efficiency is key issue!



Questions to ask in high performance computing

- **Do I understand the performance behavior of my code?**
  - What is (or should be) the principal hardware bottleneck?
  - 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 monitoring / microbenchmarking may help clear up the situation
- **Use your brain! Tools may help, but you do the thinking.**