Erlangen Regional Computing Center

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Performance Engineering

Fundamentals

High Performance Computing

Environment

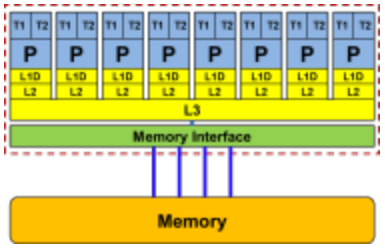
Factors influencing performance:

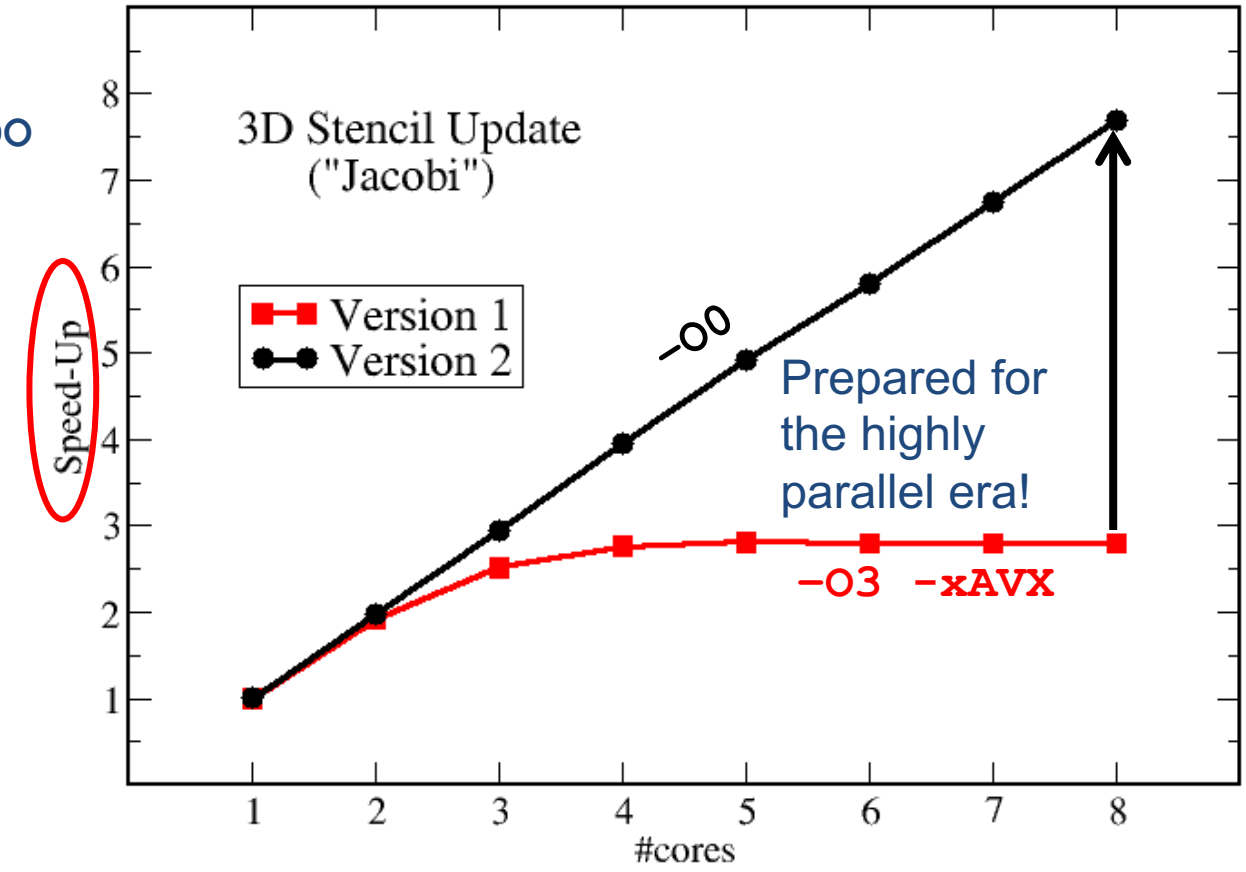
- **Implementation** (programming language, optimization techniques)
- **Code generation** (compiler used and compiler options)
- **System configuration** (also including OS settings)
- **Execution environment** (thread affinity and resource allocation)

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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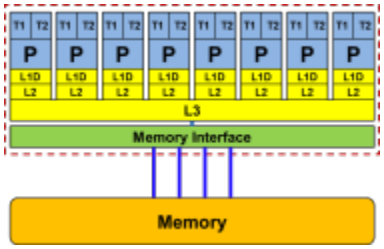
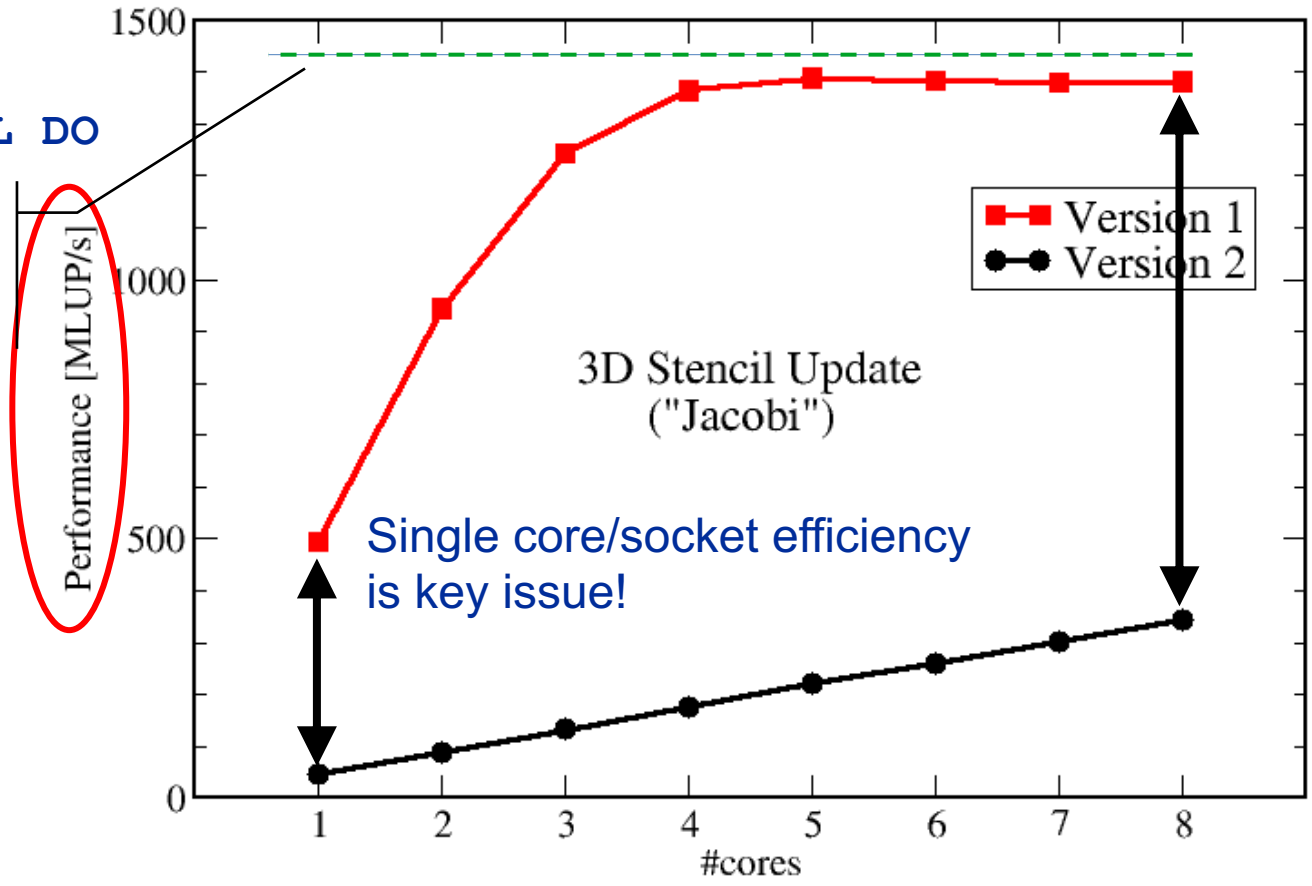
```

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





Focus on time to solution

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- Some metrics used in PE publications:
  - MFlops/s
  - Cache miss rate
  - Speedup

Time to solution is all that matters!

Runtime contributions and critical path

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- Every activity adds a **runtime contribution**
- Simplest case: all runtime contributions accumulate to the **time to solution**
- Due to **concurrency** runtime contributions can **overlap** with each other
- **Critical path** is the series of runtime contributions, that do not overlap and form the total runtime

Anything that takes time is only relevant for optimization if it appears on the critical path!

Parallel execution

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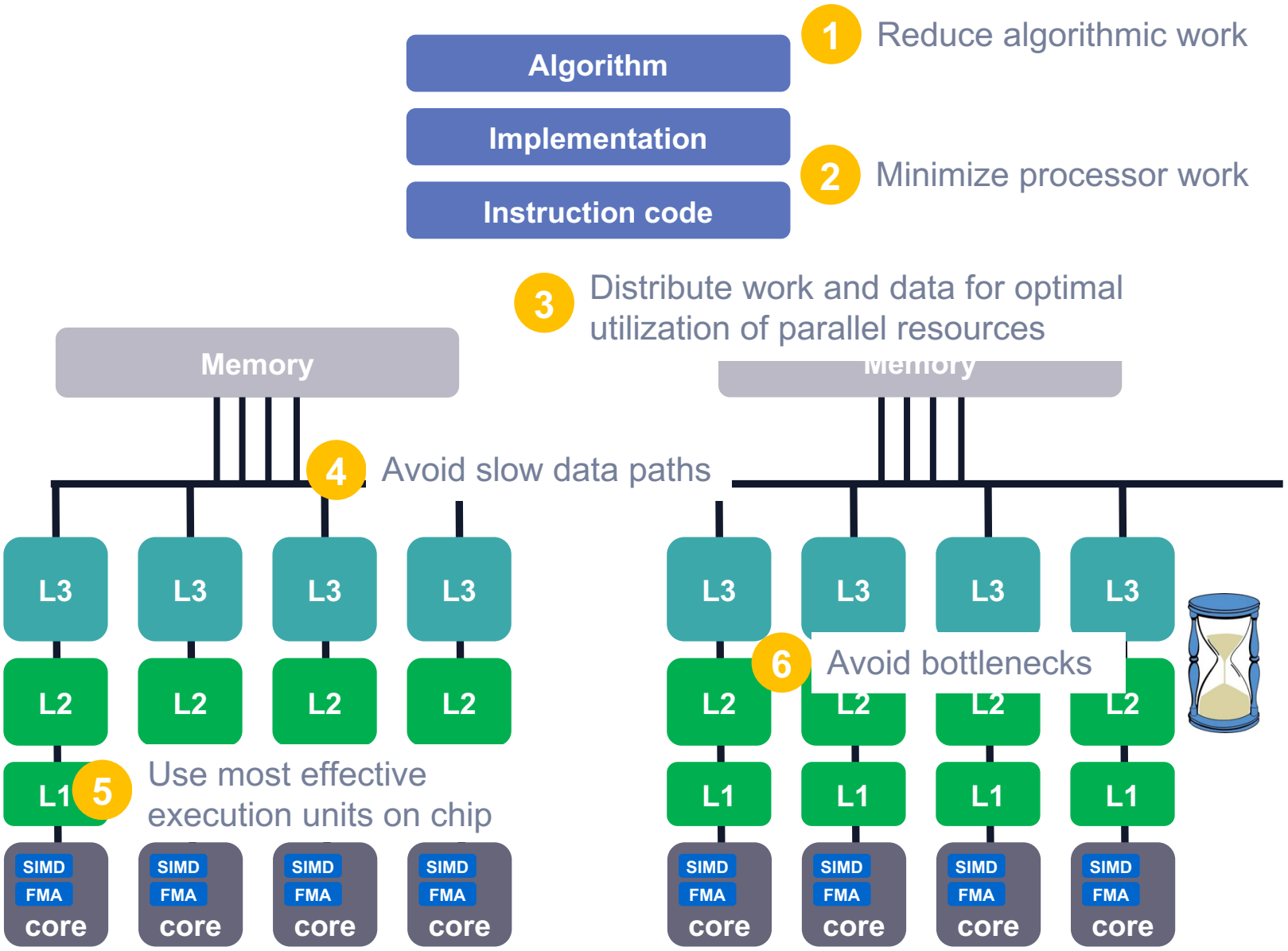
Factors limiting speedup:

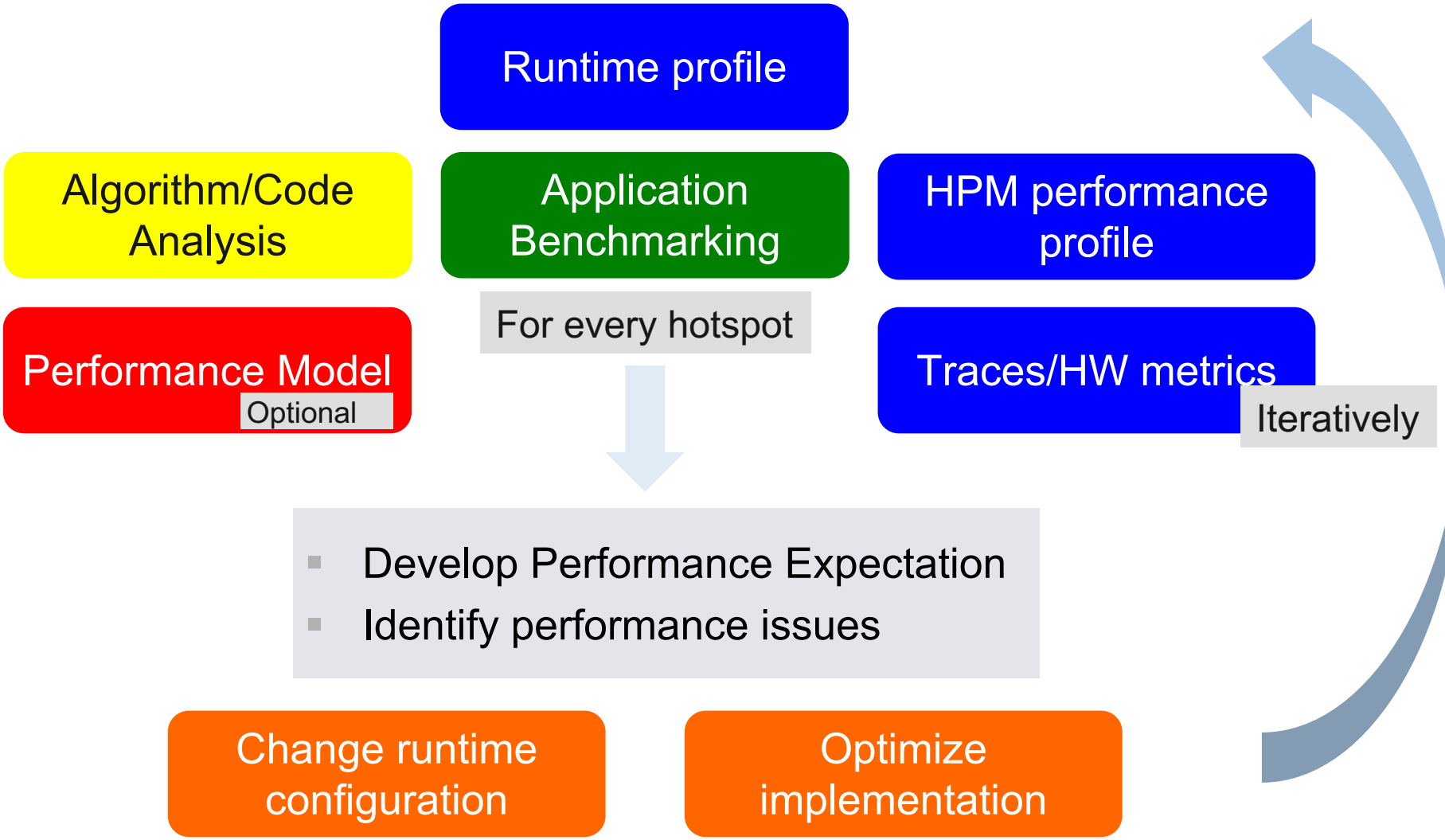
- **Load balancing**: Can work be perfectly distributed on parallel execution resources?
- **Dependencies**: Are there dependencies that add to the critical path?
- **Communication overhead**: Is there any data transfer time that adds to the critical path?
- **Instruction overhead**: Additional work that is required to implement an efficient parallel execution.

All but the last one (which adds to the processor work) are experienced as additional waiting times.

Optimizing code: The big Picture



Performance Engineering process



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.