Fachhochschule Nordwestschweiz

Module Concurrent Programming

Module Concurrent Programming 8Ibb

Lecturer: Daniel Kröni
Contact: daniel.kroeni@fhnw.ch
Email Subject: "[conpr] Your Request"

Time: Monday: 12:15-13:00 / 13:15-14:00 / 14:15-15:00
Room: 6.2H05

Course Material (Created by D. Gruntz and D. Kröni)
Active Directory: *E1811_Unterrichte/E1811_Unterrichte_I/8Ibb/conpr/*

Examination: **15.04.2019; 12:15 - 13:45, 1.021**

Module Concurrent Programming 4Ia

Lecturer: Daniel Kröni
Contact: daniel.kroeni@fhnw.ch
Email Subject: "[conpr] Your Request"

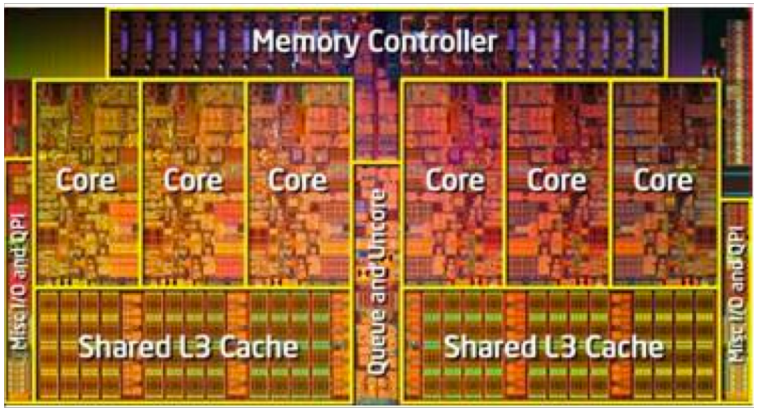
Time: Tuesday: 8:15-9:00 / 9:15-10:00 / 10:15-11:00
Room: **1.013**

Course Material (Created by D. Gruntz and D. Kröni)
Active Directory: *E1811_Unterrichte/E1811_Unterrichte_I/4Ia/conpr/*

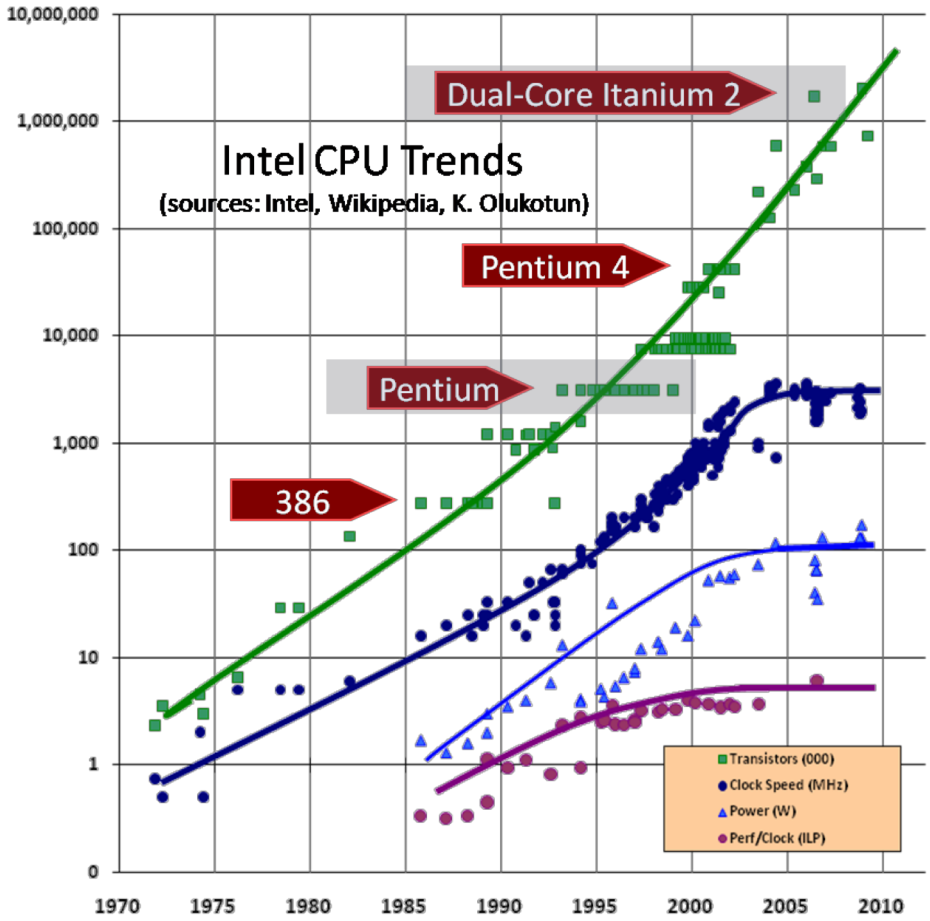
Examination: **16.04.2019; 8:15 – 9:45, 6.-1D13**

The Free Lunch is Over![1]

- **Past 30 years**
  - Clock speed
- **Now**
  - Multicore



But multi-core CPUs will have nearly no impact on most current applications !



[1] http://www.gotw.ca/publications/concurrency-ddj.htm

Multicore CPUs are here!

769.–
Huawei Mate 10 Pro (6", 128GB, Dual SIM, 20MP,

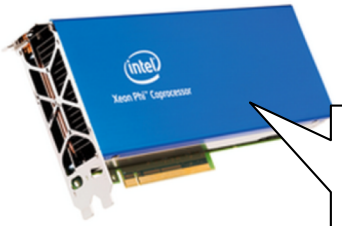
Octa Core!

28 Cores!

Intel
CPU Xeon Platinum 8176 2.1 GHz

32 Cores!

AMD
CPU Ryzen Threadripper 2990WX 3.00 GHz



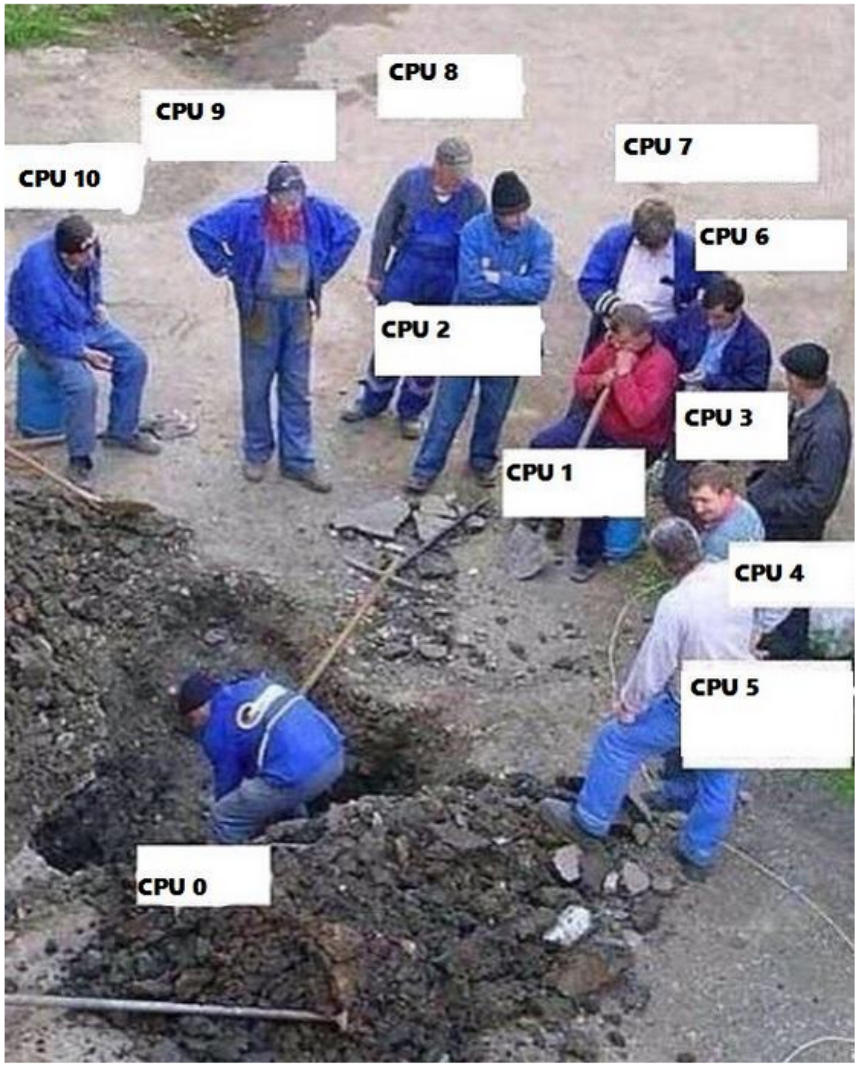
68 Cores
272 HW Threads

5120 Cuda Cores

PNY
Grafikkarte NVIDIA Tesla V100 32GB

Özgür Akgün @ozgurakgun · Apr 11

this is indeed how most programs work on a multicore computer!



Amdahl's Law

- **Formula to predict the maximum speedup using multiple processors (N) based on the proportion of parallelizable (p) and serial (1-p) component of a program.**

$$\text{Speedup} \leq \frac{1}{(1-p) + \frac{p}{N}}$$

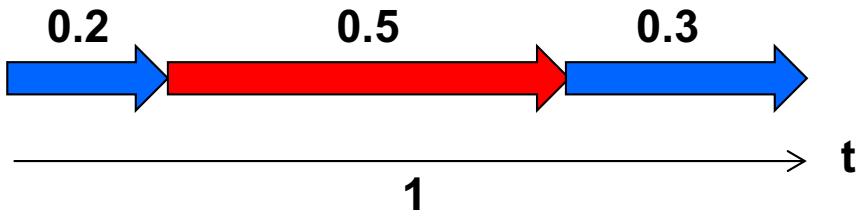
- **Speedup is limited by the time needed for the sequential fraction of the program**

All concurrent applications have some sources of serialization!

Amdahl's Law: Example (p = 0.5)

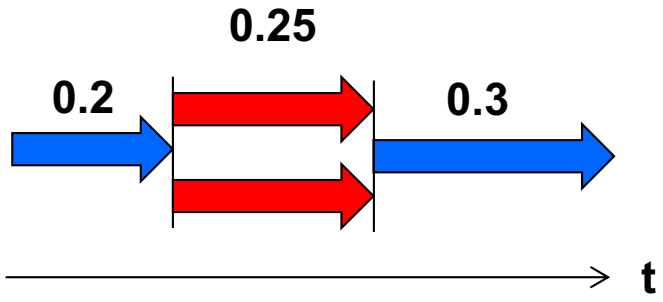
$$\frac{1}{(1-p) + \frac{p}{N}}$$

N = 1



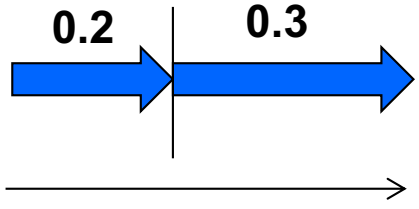
$$S = \frac{1}{(1 - 0.5) + 0.5} = 1$$

N = 2



$$S = \frac{1}{(1 - 0.5) + 0.25} = 1.33$$

N = ∞

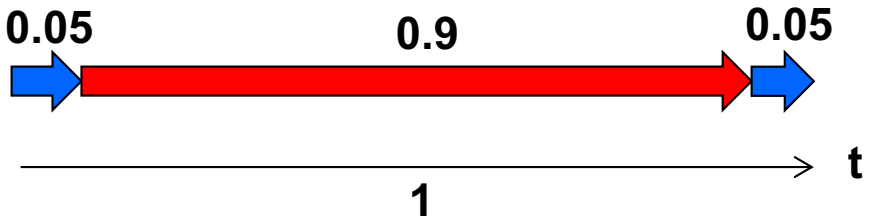


$$S = \frac{1}{(1 - 0.5) + 0} = 2$$

Amdahl's Law: Example (p = 0.9)

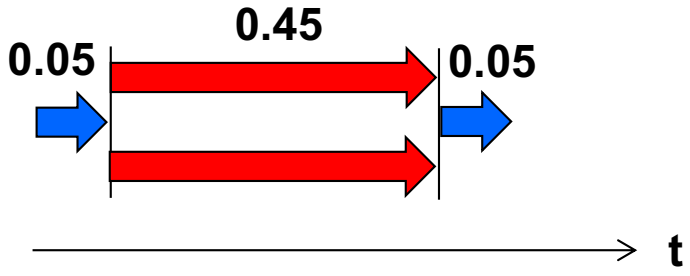
$$\frac{1}{(1-p) + \frac{p}{N}}$$

N = 1



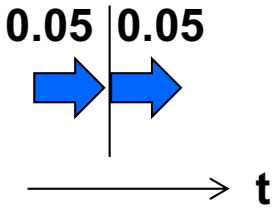
$$S = \frac{1}{(1 - 0.9) + 0.9} = 1$$

N = 2



$$S = \frac{1}{(1 - 0.9) + 0.45} = 1.82$$

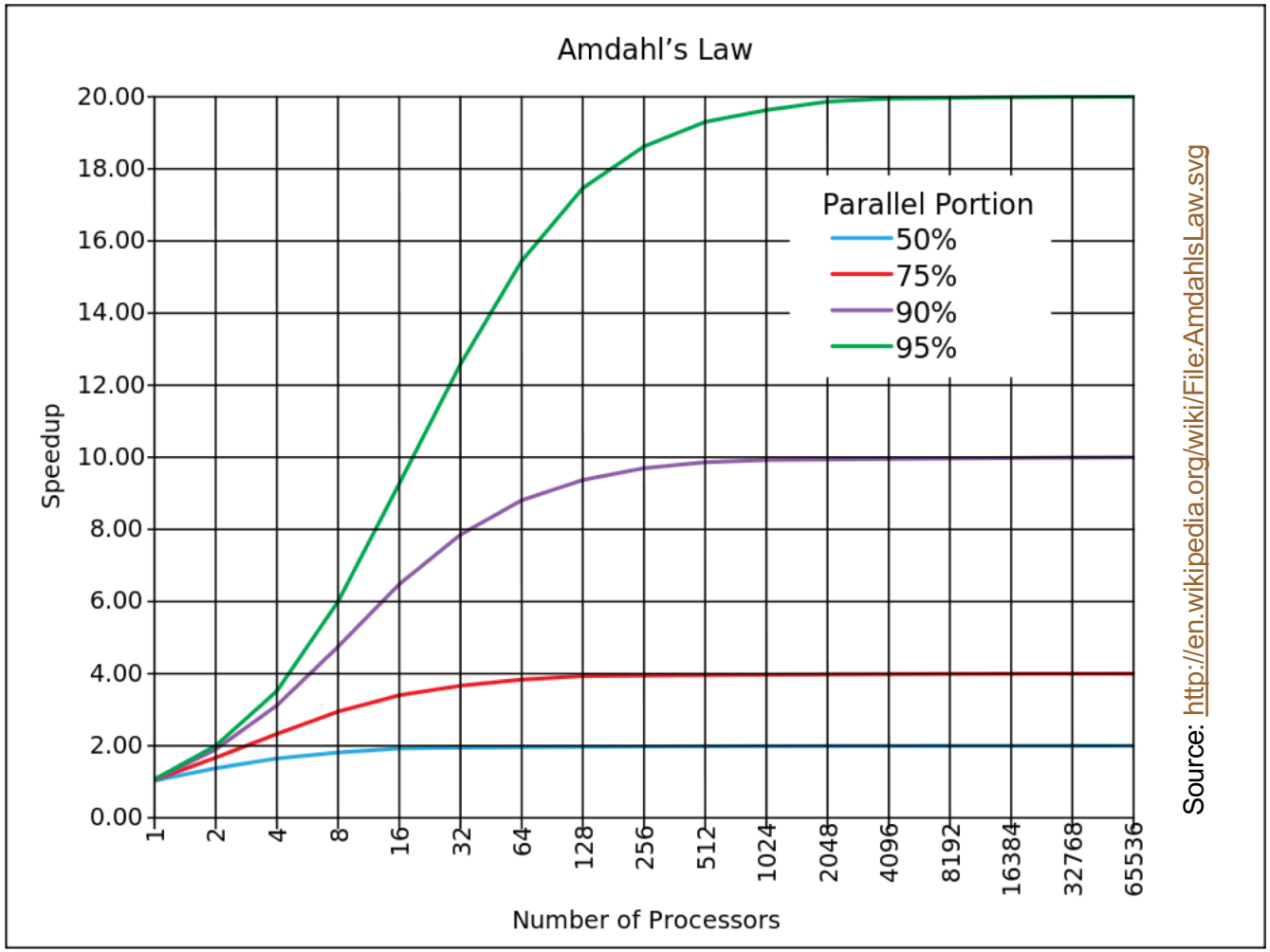
N = ∞



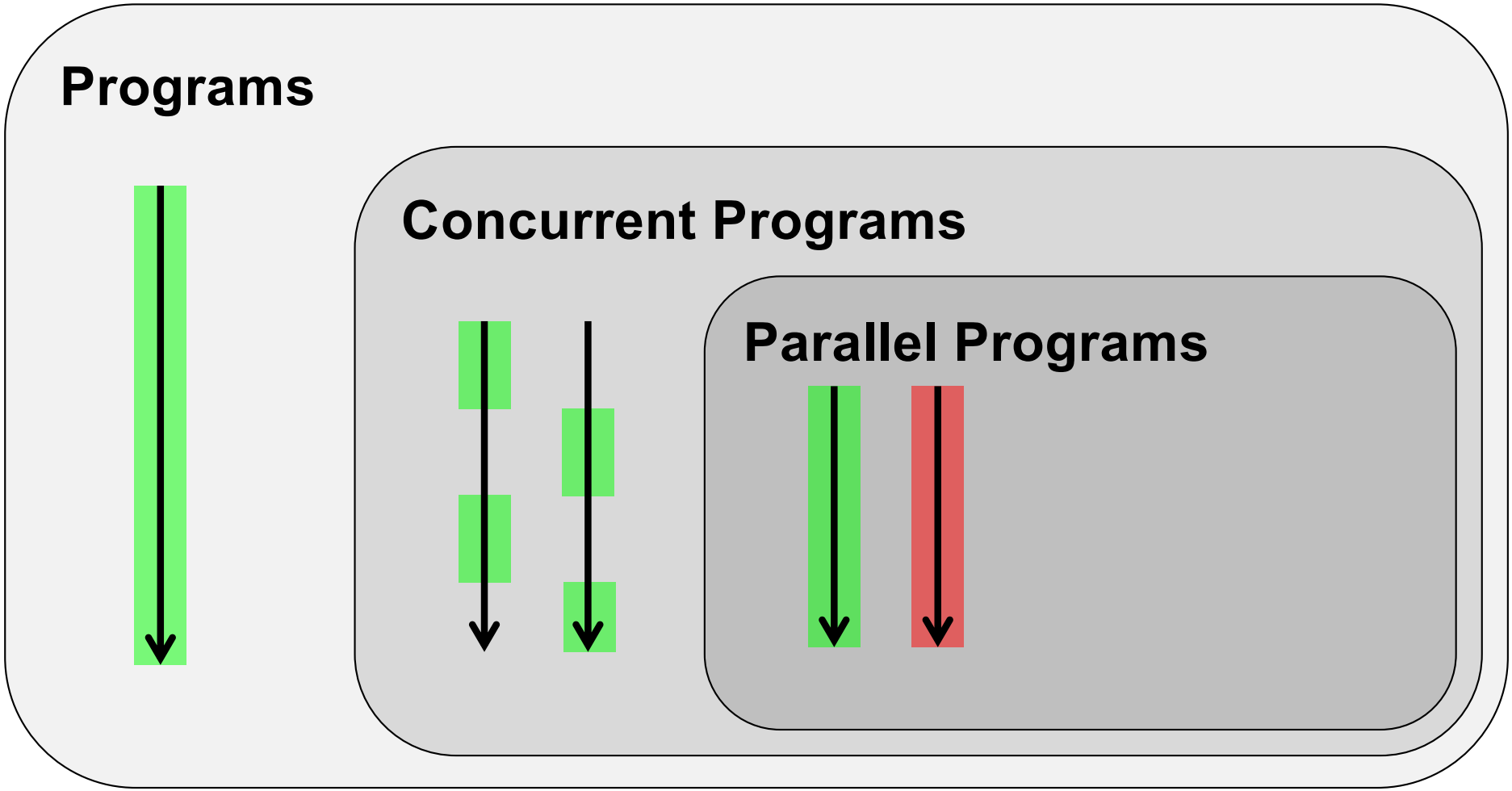
$$S = \frac{1}{(1 - 0.9) + 0} = 10$$

Amdahl's Law

$$\frac{1}{(1-p) + \frac{p}{N}}$$



Concurrent Programming



Concurrent vs Parallel

- **Concurrent Program**
  - has multiple logical threads of control
  - Concurrency is about dealing with lots of things at once
  - To solve a concurrent problem you have to handle events which can happen simultaneously
  - Concurrent programs are often non-deterministic (result depends on timing of events)
- **Parallel Program**
  - executes different parts of the computation simultaneously (in parallel)
  - Parallelism is about doing lots of things at once
  - To solve a parallel problem, the problem has to be broken down into pieces
  - Parallelism doesn't imply non-determinism

Parallelism: Omnipresence

- **Modern computers are parallel on many different levels**
  - Bit-level parallelism
    - 64bit computer is faster than an 8bit computer
  - Instruction-level parallelism (with the illusion that everything is sequential)
    - Pipelining
    - Out of order execution
    - Speculative execution
  - Data parallelism (SIMD)
    - GPUs have evolved into extremely powerful data parallel processors
  - Task-level parallelism
    - Multi-core machines, typically shared memory
    - => memory model

Concurrency: Omnipresence

- **Threads are everywhere**
  - Even if a programmer does not explicitly create threads, frameworks may create threads, and code called from these threads must be thread-safe!

- **Examples in Java**
  - Threads are used by every Java application
    - GC-Thread
    - Finalization-Thread
  - Java FX applications:
    - JavaFX Application Thread (Event dispatcher)
    - QuantumRenderer Thread
  - Web application frameworks:
    - Different requests are executed by different threads

Consequences

- **Applications need to be concurrent if you want to exploit multicores**
  - Existing applications have to be redesigned
- **Good support of programming languages/libraries**
  - Java [java.util.concurrent]
    - Biased towards shared memory and the required coordination mechanisms
  - Special language concepts become mainstream
    - Functional Programming (Immutability, side effect avoidance)
    - Actor model (Erlang, Scala)
    - Software transactions (STM: Clojure, Scala)

The biggest sea change in software development since the OO revolution is knocking at the door, and its name is Concurrency. ***[Herb Sutter]***

Risks / Problems

- **Safety hazards**
  - Nothing bad ever happens
  - Race conditions
- **Liveness hazards**
  - Something good eventually happens
  - Deadlock, Livelock, Starvation
- **Performance hazards**
  - Over-Synchronization: Amdahl's Law
  - Context switches are not free: Saving and restoring execution context
- **Testing is not reliable**
  - Scheduling is not deterministic
- **Debugging is often impossible**
  - Heisenbugs (bug disappears when trying to observe it)

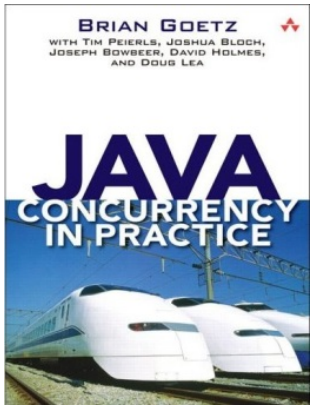
```
@NotThreadSafe
public class IdGenerator {
   private int currentId;

   public int nextId() {
      return currentId++;
   }
}
```

Goals

- **The Students**
  - … know typical problems and hassles in the context of concurrent programs
  - … know and can apply abstract solution patterns for such problems
  - … know different paradigms to solve concurrency problems such as actors and software transactions
  - … know the memory model used by Java programs
  - … can write correct concurrent programs

Reference for the first part

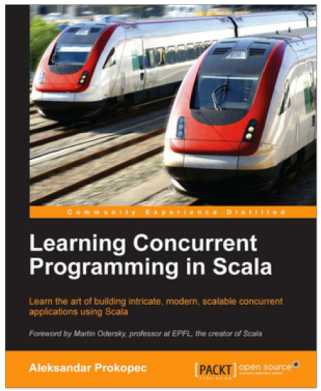
- ***Java Concurrency in Practice***
  - Brian Goetz, Tim Peierls, Joshua Bloch, Joseph Bowbeer, David Holmes, Doug Lea
  - Addison-Wesley Professional (May, 2006)
  - ISBN-13: 978-0321349606



- ***Nebenläufige Programmierung mit Java***
  - Jörg Hettel, Manh Tien Tran
  - dpunkt Verlag (August, 2016)
  - ISBN-13: 978-3-86490-369-4

Reference for the second part

- ***Learning Concurrent Programming in Scala***
  - Aleksandar Prokopec
  - PACKT Publishing (November, 2014)
  - ISBN-13: 978-1783281411



Writing correct programs is hard;
writing correct concurrent programs is harder

Schedule 8Ibb

Woche	Datum	Thema
1	18.02.19	Intro, Threads
2	25.02.19	Locks
3	04.03.19	Condition Synchronization
4	11.03.19	Java Memory Model
5	18.03.19	Sharing Objects
6	25.03.19	Non Blocking Algorithms / Atomics
7	01.04.19	Synchronizers
8	08.04.19	Task based concurrency
9	15.04.19	Prüfung
	22.04.19	Osterferien
10	29.04.19	Scala Intro
	06.05.19	Projektwoche
11	13.05.19	Scala Concurrency
12	20.05.19	Software Transactional Memory
13	27.05.19	Actor Model
14	03.06.19	Testing
	10.06.19	Pfingsmontag

Schedule 4la

Woche	Datum	Thema
1	19.02.19	Intro, Threads
2	26.02.19	Locks
3	05.03.19	Condition Synchronization
4	12.03.19	Java Memory Model
5	19.03.19	Sharing Objects
6	26.03.19	Non Blocking Algorithms / Atomics
7	02.04.19	Synchronizers
8	09.04.19	Task based concurrency
9	16.04.19	Prüfung
	23.04.19	Osterferien
10	30.04.19	Scala Intro
	07.05.19	Projektwoche
11	14.05.19	Scala Concurrency
12	21.05.19	Software Transactional Memory
13	28.05.19	Actor Model
14	04.06.19	Testing
	11.06.19	TBD