Concurrent Systems

Nebenläufige Systeme

I. Introduction

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October 17, 2017

Agenda

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Summary

Abstract Concept

- meaning of the lecture labelling in linguistic terms [6]:
con·cur·rent (lat.) *concurrens* : preposition of *concurrere*

sys·tems plural of (gr.) *systēmas* : to place together

Abstract Concept

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con·cur·rent (lat.) *concurrens* : preposition of *concurrere*
  1. occurring at the same time; existing together
  2. meeting in or going toward the same point; converging
  3. acting together; cooperating
  4. in agreement; harmonious
  5. exercised equally over the same area

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sys·tems plural of (gr.) *systēmas* : to place together
  1. a set of arrangements of things so related or connected as to form a unity or organic whole
  2. a set of facts, principles, rules, etc. classified or arranged in a regularly, orderly form so as to show a logical plan linking the various parts
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Concurrency as a System Property

- simultaneous execution of potentially interacting computations
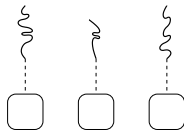 - with the latter being logical (cooperating) or incidental (contending)
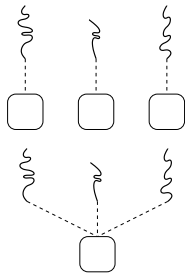
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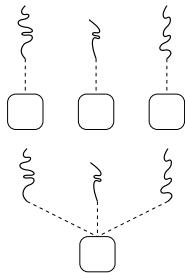- concurrence in the program flow is due to:

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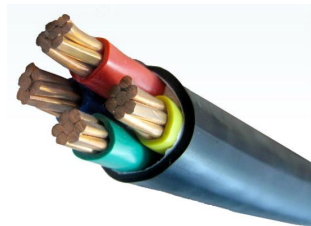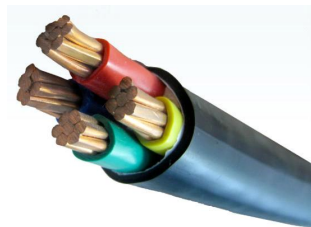- focus is on **parallel processing** of the same **non-sequential program**
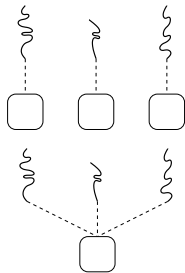
- parallel-computer engineering is pervasive

  multi-core ▪ conventional characteristic

  uni-core ▪ rather unconventional, but rife

- by the way: multi-core $\subset$ many-core

  multi ▪ little tens ("handful") of cores

  many ▪ several tens of cores and more

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- exposure to parallelism is indispensable [7]

  ▪ mandatory at least for operating systems

28 cores, uniformly distributed across four tiles ☺

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- many-core processors make core multiplexing almost superfluous
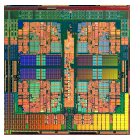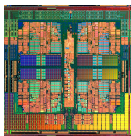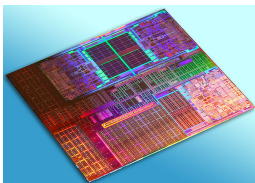 - unless latency hiding becomes an issue within a parallel process

2 cores

2 cores   4 cores

2 cores   4 cores   8 cores

2 cores 4 cores 8 cores 16 cores

2 cores   4 cores   8 cores   16 cores
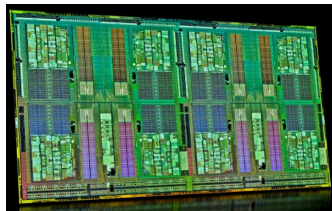
32 cores
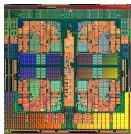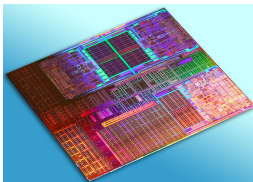
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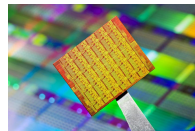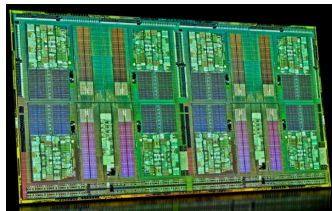
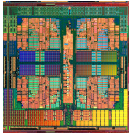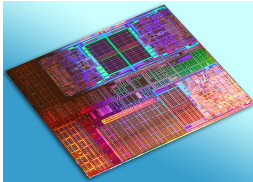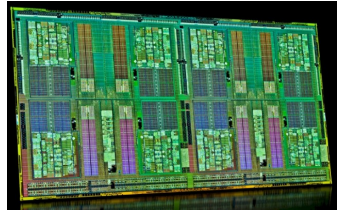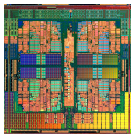48 cores 32 cores
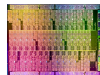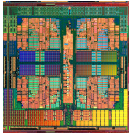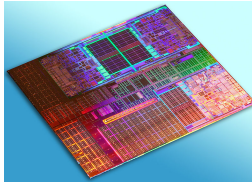
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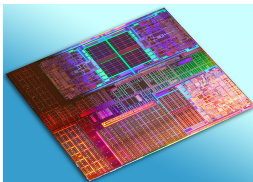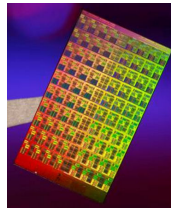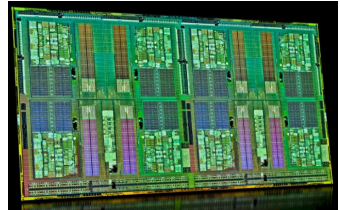80 cores 48 cores 32 cores
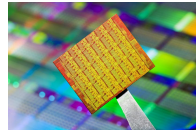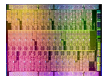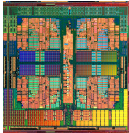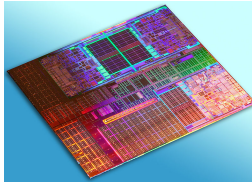
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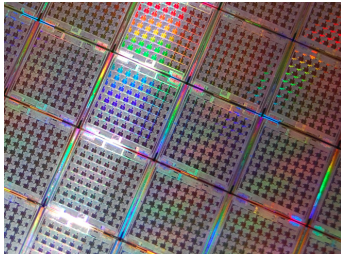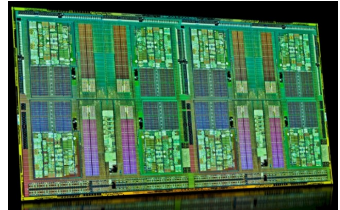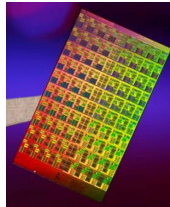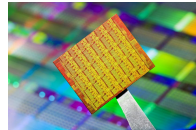
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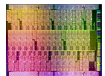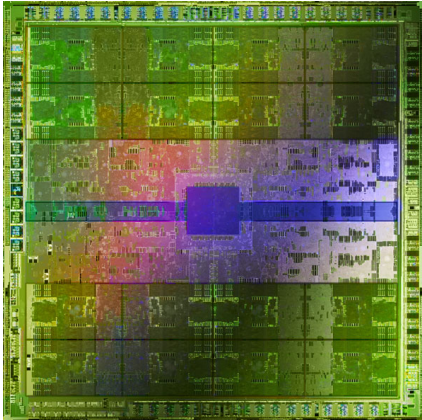
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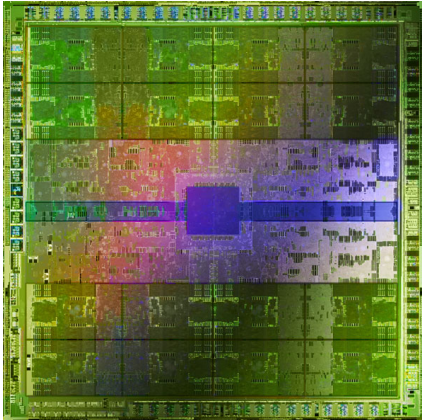
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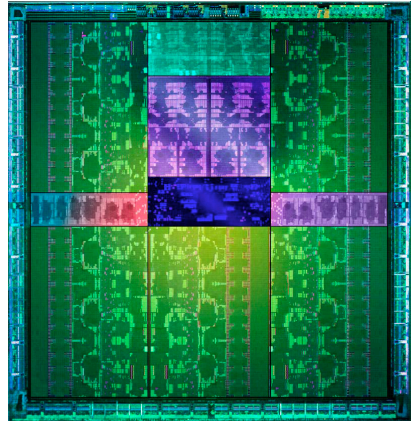
1 536/3 072 cores
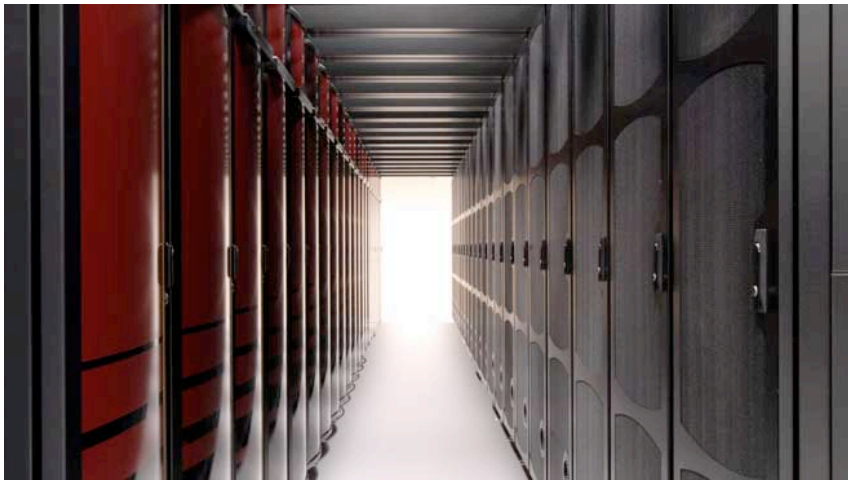
3 120 000 cores
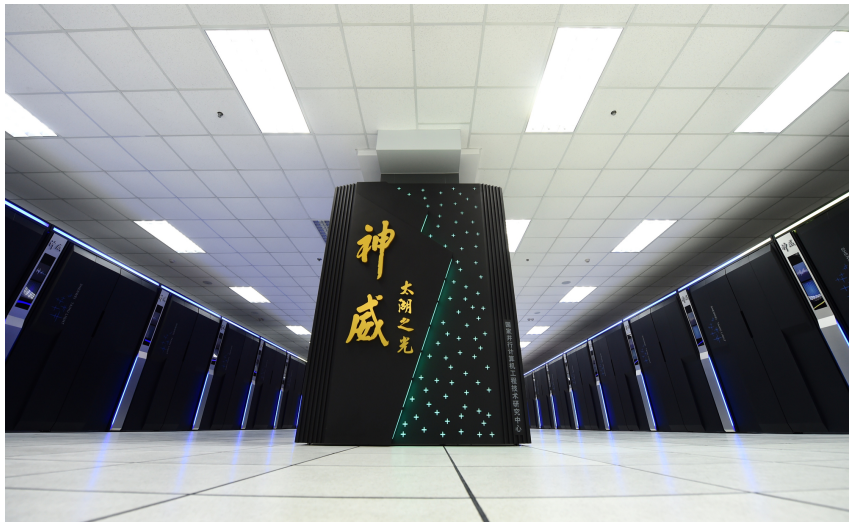
10 649 600 cores

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- cache **coherency**: memory *property*

- memory (also: cache) **consistency**: memory *state*

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    - in functional terms: instruction set architecture (ISA)
    - but also non-functional: latency, clock speed, energy use
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    - different in at least one of those aspects

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    - globally direct memory access: load/store operations
    - maybe partitioned global address space (PGAS)
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    - globally indirect memory access: message passing

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Outline

Fundamentals

Introduction:

1. overview, organisation—today's lecture. . .

Fundamentals

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General topics and basic principles:

2. notion of "concurrency" against the background of resource sharing
   - causality ("cause and effect"), synchronisation, indivisibility
3. notion of "process" and difference to "program"
   - sequential, non-sequential, concurrent, interacting
4. critical (program) sections and their typical patterns
   - race conditions/hazards: lost update, lost wakeup
5. elementary operations and other hardware aspects
   - TAS, CAS, and LL/SC versus caches, coherence, and interference

Classic and folklore:

6. lock algorithms
   - contention, backoff, ticket, interference
7. semaphore
   - binary (vs. "mutex"), general/counting, bolt, set
8. monitor and condition variable
   - signalling semantics: Hansen, Hoare, Mesa, Java
9. deadlock and livelock
   - prevention, avoidance and detection & resolution

Avant-garde and other:

10. algorithms based on indivisible memory-write instructions
    - assuming vertical (stack-like) overlapping
    - interrupt-transparent synchronisation

11. algorithms based on dedicated machine instructions
    - assuming horizontal (congeneric) overlapping
    - compare and swap (CAS), load linked (LL) and store conditional (SC)

12. transactional memory
    - AMD's advanced synchronisation facility (ASF)
    - Intel's transactional synchronisation extensions (TSX)

13. progress guarantees
    - obstruction-, lock- and wait-free behaviour
    - constructive (favoured) and analytical (neglected) approaches

Pickings

State of the art and recapitulation:

14. current research work and advances in modern operating systems
    - remote-core locking [4], unlocking energy [3]
    - read-copy update [5], big kernel lock

15. wrap-up and words in a personal matter
    - retrospection and lessons learned
    - research projects on these topics at the chair
    - perspectives for advanced training: bachelor, master, doctoral thesis

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Hint (Lecture)

*Main objective is to impart knowledge on concurrent systems from the **system programming point of view**. Wide emphasis is on the internals of synchronisation concepts and primitives as well as the implications of the respective implementations. Application of these methods for parallel programming takes a back seat.*

Outline

Preface

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Organisation

Summary

- depends on the German linguistic abilities of the participants

Language of Instruction

- depends on the German linguistic abilities of the participants

English
- preferred working language
- strict choice if at least one attendee does not agree on German

German
- in case of doubt or missing answer, German is fallback position[1]

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[1]Studying abroad also means *living* abroad—and to take part and share in Franconian social life. The latter *soft skills* cannot be overestimated.

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- written material (slides or handouts, resp.) will be English
  - with technical terms also stated in German, where applicable

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- relate it with previous knowledges

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  - attend presentation, listen, and discuss topics treated
  - reinforce learning matter, reflect

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  - computer architecture (GRA)   I3
  - system programming (SP, SPiC, GSPiC)   I4
  - operating systems (BS), operating-systems engineering (BST)   I4
  - real-time systems (EZS)   I4

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- teaching material presented in the **lecture room**:
  - follow "Lehre" (Eng. *teaching*) at `https://www4.cs.fau.de`
  - copies of the slides are made available as handouts free of charge
  - supplemented by secondary literature as and when required
    - see the bibliography at the bottom of each handout
  - glossary of terms at `https://www4.cs.fau.de/~wosch/glossar.pdf`

■ deepen knowledge by means of direct experience

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- assignments are to be processed in teamwork: discretionary clause
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[2]abbr. for (Ger.) *Webanmeldefrickelformular Enterprise Logic*

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■ **computer work** under individual responsibility
- registration is not scheduled, reserved workplaces are available
- in case of questions, a CS exercise instructor is available

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Requirements

- **hard skills** (computer-science expertise)
  - mandatory
    - structured computer organisation
    - algorithm design and development
    - principles of programming in C or C++
    - ↪ knowledge gaps will not be closed actively: no extra tuition
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- **soft** (personal, social, methodical) **skills**
  - staying power, capacity of teamwork, structured problem solving

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Outline

Subject Matter

- coordination of cooperation and concurrency
  - between interacting (i.e., control- or data-flow dependent) processes
  - with emphasis on explicit synchronisation

- against the background of two dimensions of concurrency

vertical	• overlapped execution at operating-system machine level
	• process preemption (partial virtualisation)
horizontal	• overlapped execution at instruction set architecture level
	• processor (core) multiplication

- in-depth study of approaches suitable (not only) for operating systems
  - advanced studies to the range of topics on system programming
  - basic studies to concurrent (i.e., non sequential) programming

- fundamental understanding of different synchronisation paradigms
  - blocking versus non-blocking synchronisation
  - where is what paradigm mandatory, optional, beneficial, or adversely...

Subject Matter

- coordination of cooperation and concurrency
  - between interacting (i.e., control- or data-flow dependent) processes
  - with emphasis on explicit synchronisation
- against the background of two dimensions of concurrency
  - vertical
    - overlapped execution at operating-system machine level
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