Hasso Plattner Institut

IT Systems Engineering | Universität Potsdam

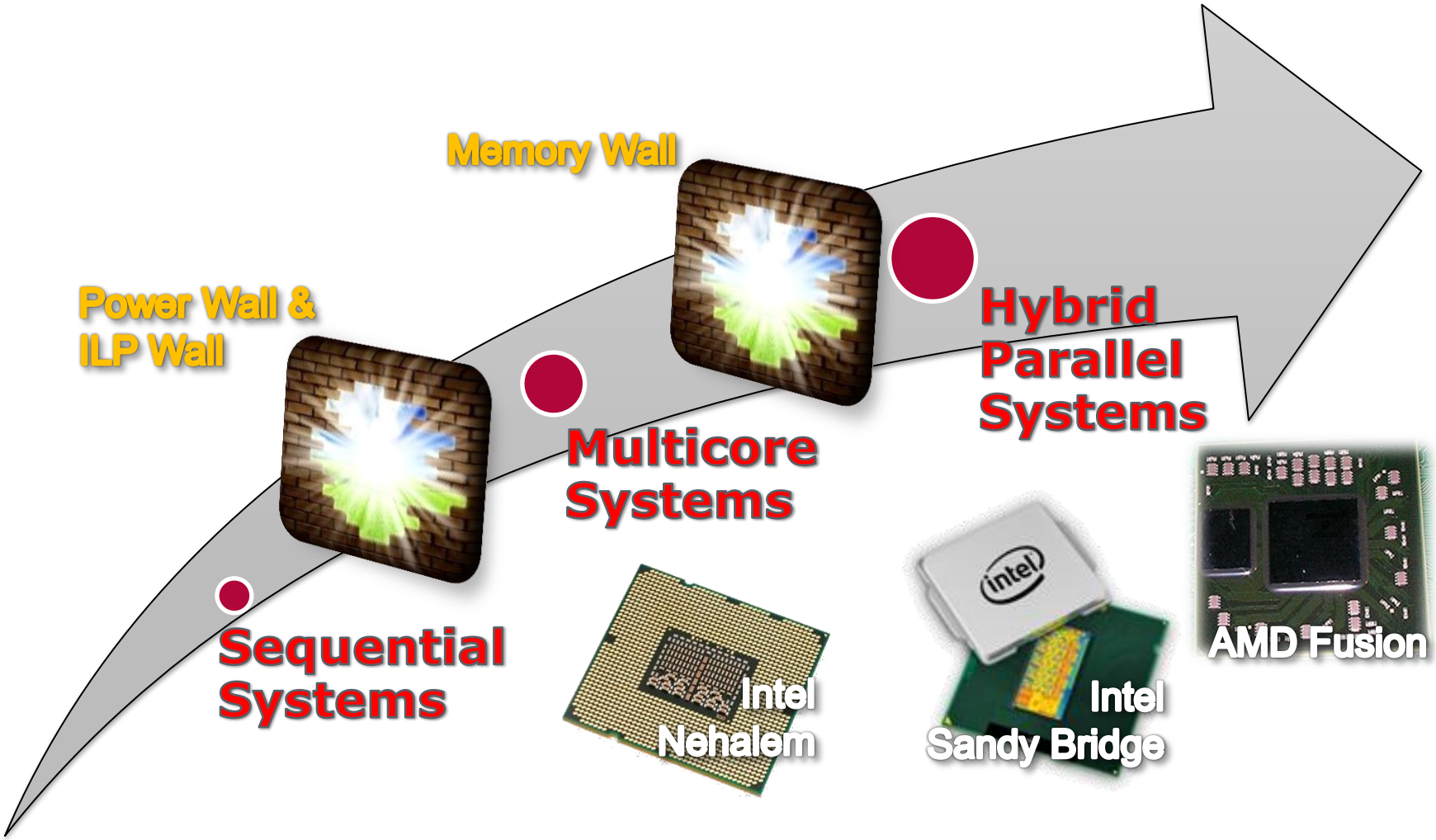
Exotic Methods in Parallel Computing [Introduction]

Frank Feinbube, Fahad Khalid

Exotic Methods in Parallel Computing

Dr. Peter Tröger

Architectural Shift



Hybrid Computing

Flavors of massively multi-core systems:

- Radically new architectures under evaluation (Intel SCC)
- Accelerators accompany general purpose CPUs (Hybrid Systems)

Hybrid Systems

- **GPU Compute Devices**
  High Performance Computing
  (3 out of top 5 supercomputers are GPU-based!)
  - Business Servers, Home/Desktop Computers, Mobile and Embedded Systems
- **Special-Purpose Accelerators**
  - (de)compression, XML parsing, (en|de)cryption, regular expression matching


The beautiful new world of
Hybrid Compute Environments

The beautiful new world of Hybrid Compute Environments

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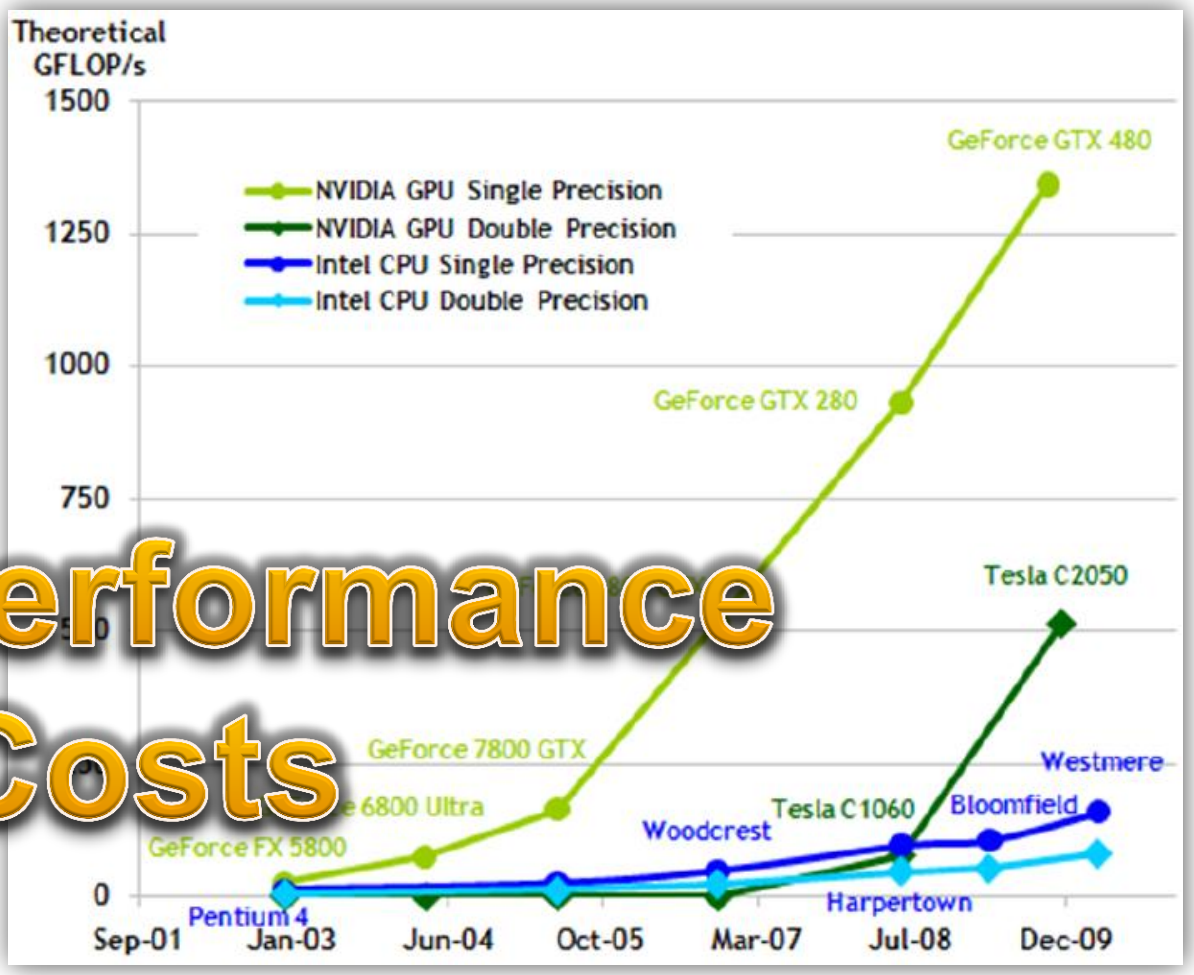


Huge Performance + Low Costs

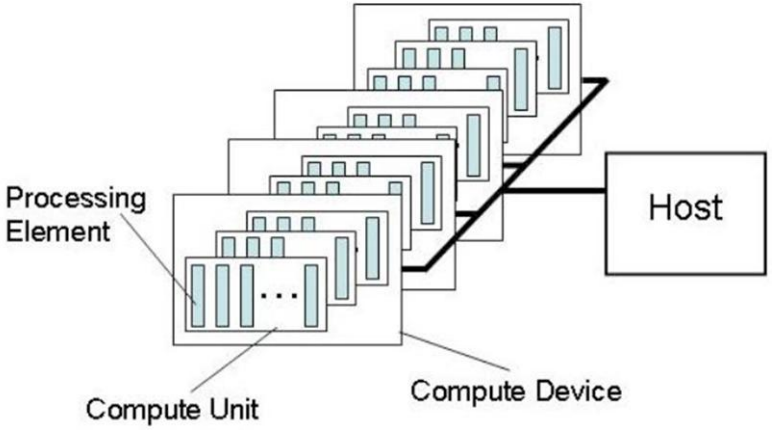
The beautiful new world of Hybrid Compute Environments

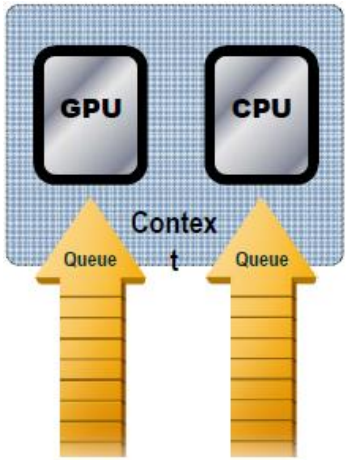
Medical, Finance
Military, Research
Video and Photo
Energy, ...

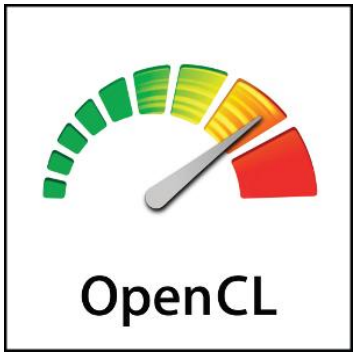
Variety of Successful Applications

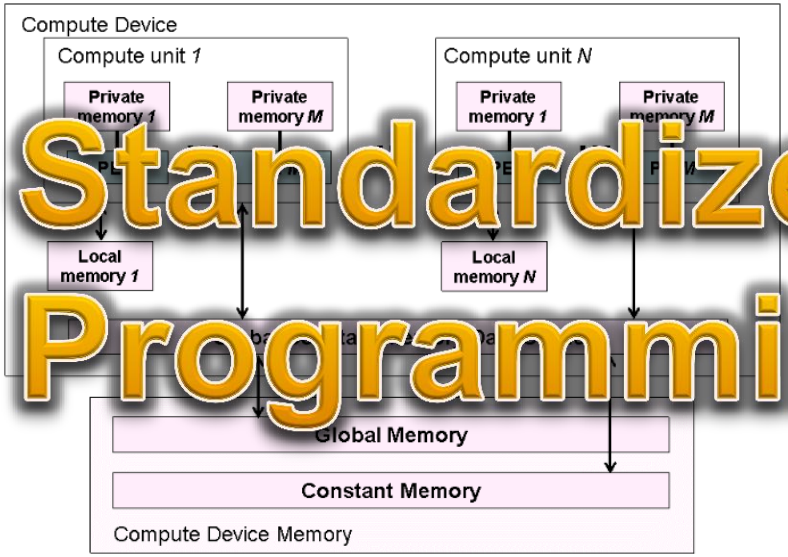
http://www.nvidia.com/object/cuda_apps_flash_new.html
http://www.nvidia.com/object/tesla_testimonials.html

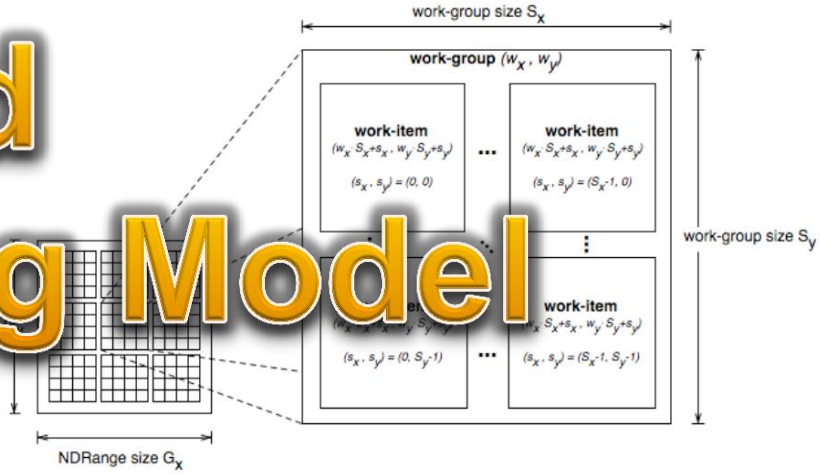
The beautiful new world of Hybrid Compute Environments









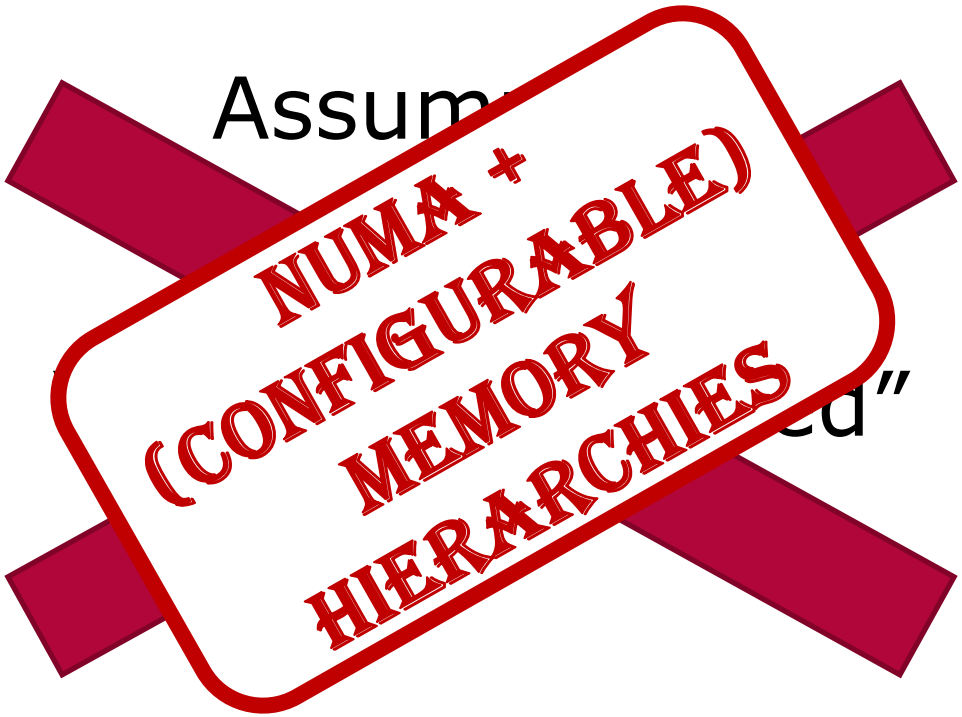


Standardized Programming Model


That would be too good
to be for free!
Assumptions
do not hold anymore

Assumptions do not hold anymore

Assumptions do not hold anymore



Assumptions do not hold anymore

Assumptions do not hold anymore

Assum

"Correc in Code

s.

RACE CONDITIONS + PRECISION HW-DEPENDENT

Assumptions do not hold anymore

Assumpt

"Op s:

* abstr tails away

* cope rity, duling,

distribution, …"

MANUAL
ACCELERATOR
MANAGEMENT

Assumptions do not hold anymore

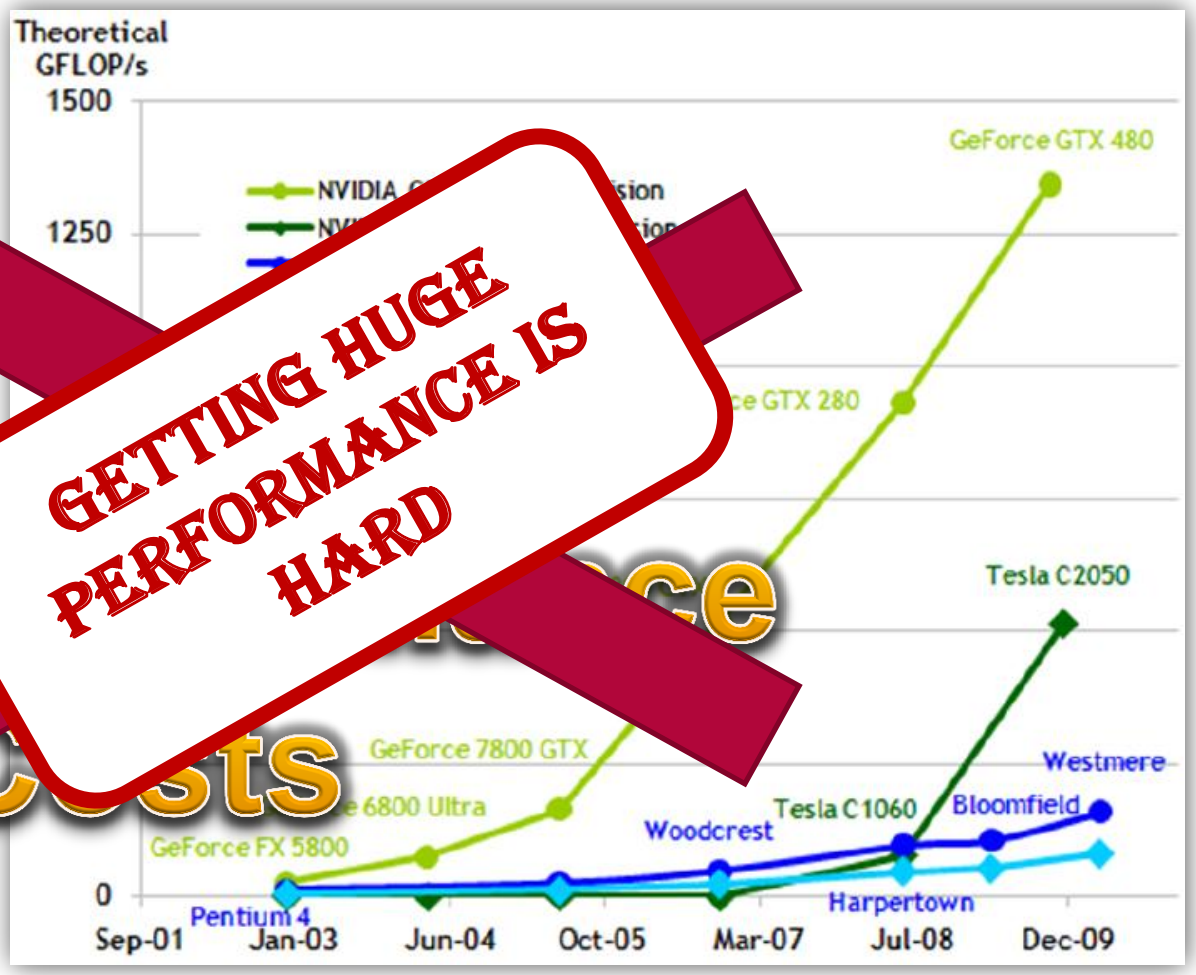
Assumpt

"Abstrac lopers to foc tication"

"Applicati n't need to unders d the hardw re"

HYBRID PROGRAMMING MODELS REQUIRE A DEEP UNDERSTANDING OF THE HARDWARE

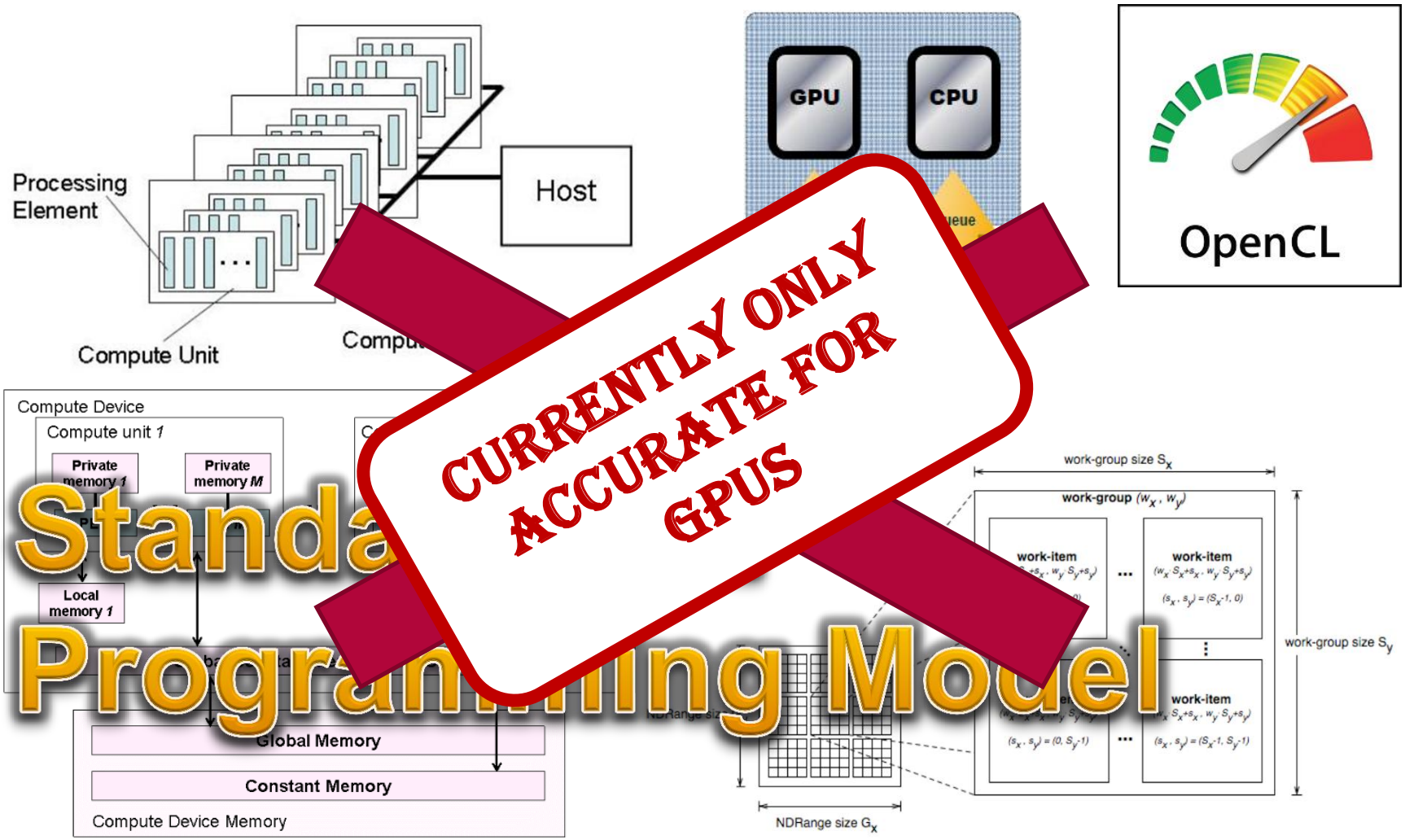
The beautiful new world of Hybrid Compute Environments?



GETTING HUGE PERFORMANCE IS HARD

Huge P ce
+ Low Costs

The beautiful new world of Hybrid Compute Environments?



The beautiful new world of Hybrid Compute Environments?

The beautiful new world of Hybrid Compute Environments?

Medical, Finance
Military, Research
Video and Photo
Energy, ...

Variety of Successful Applications

http://www.nvidia.com/object/cuda_apps_flash_new.html
http://www.nvidia.com/object/tesla_testimonials.html


What can be done?


What does the future hold?

The beautiful new world of Hybrid Compute Environments

Hasso Plattner Institut

Amazon Web Services
- Hosted GPUs
- GPU Cloud

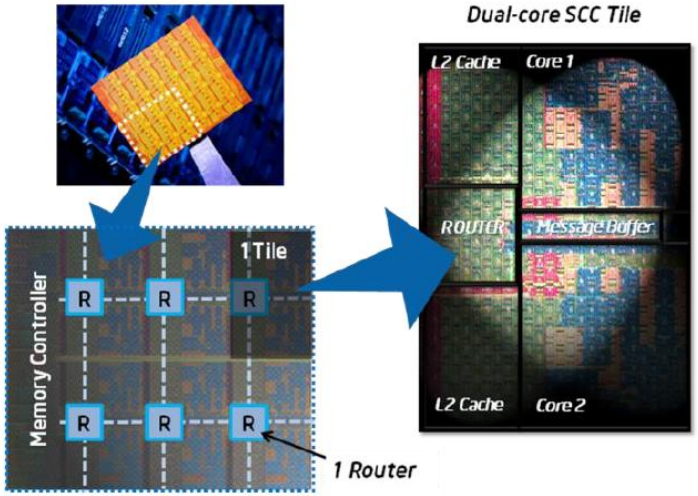
Peer 1 Hosting
- Hosted GPUs
- GPU Cloud
- Hosted Reality Server

Nimbix (Informatics Xcelerated)
- Hosted GPUs
- GPU on Demand

Penguin Computing
- Hosted GPUs
- Hosted Reality Server

GPU Cloud Computing Service Providers

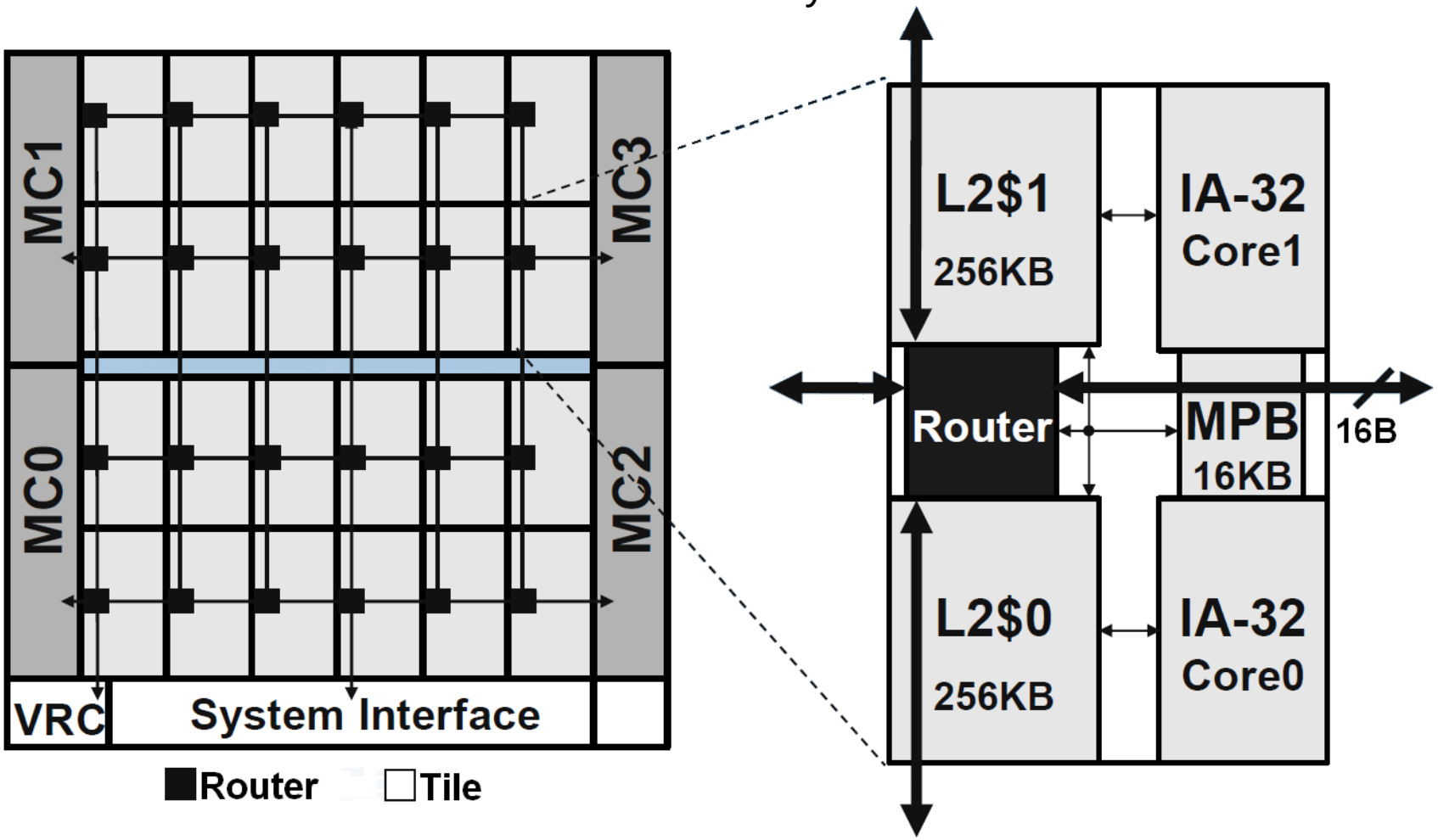
Intel Single-Chip Cloud Computer (SCC): a radically new architecture



- 24 tiles with two IA32 cores per tile
- A 24-router mesh network with 256GB bisection bandwidth
- 4 integrated DDR3 memory controllers
- Hardware support for message passing
- Power management:
  24 frequency islands, 6 voltage islands
- No hardware cache-coherency

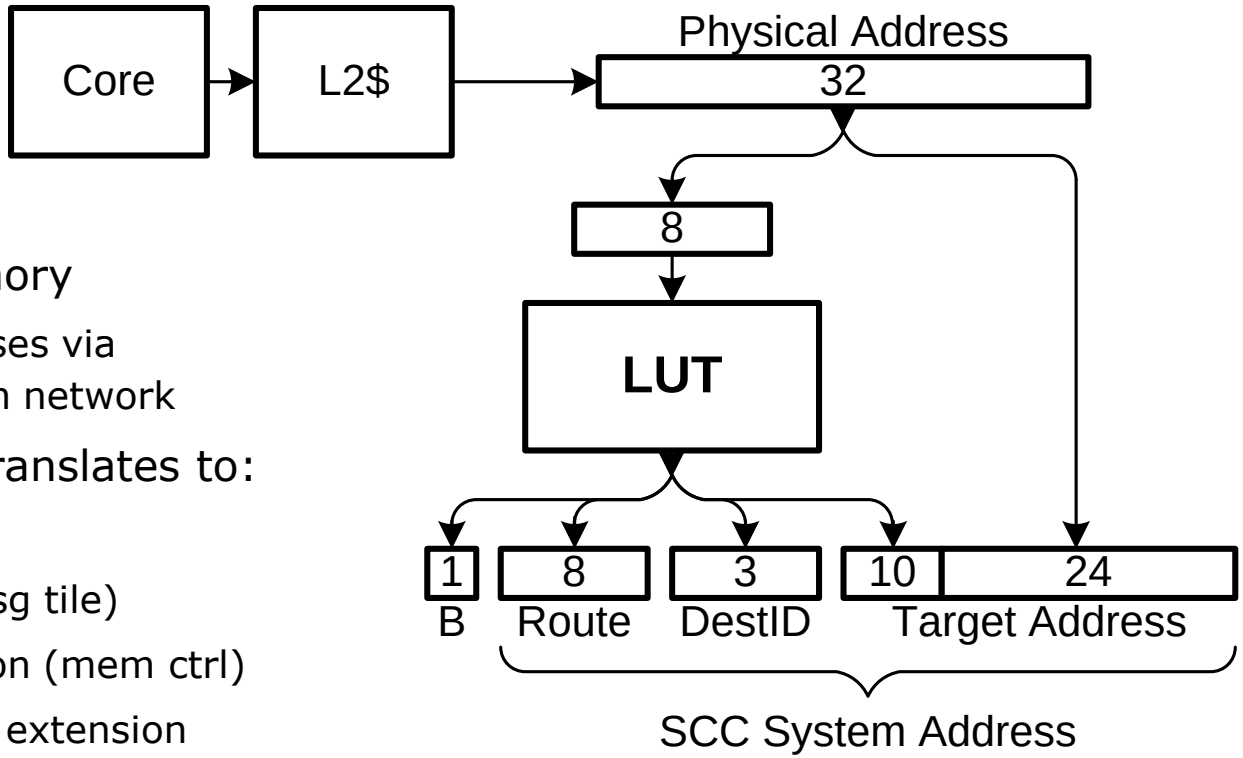
SCC Tile Architecture

SCC has 24 dual-core tiles interconnected by mesh network



Dynamically reconfigurable memory layout, no memory coherency protocols

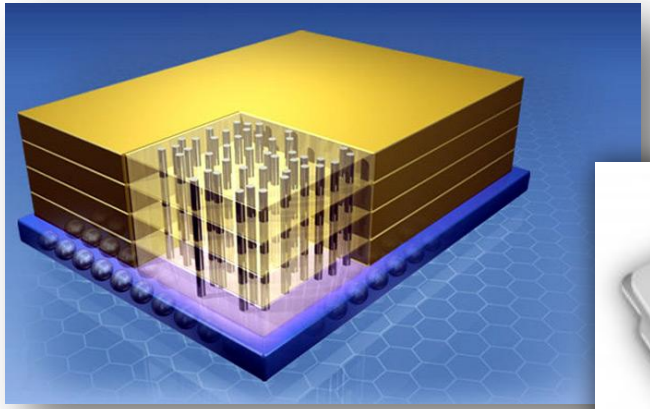
- Original Pentium: Physical Address would be seen on address bus
- On SCC: Physical addresses mapped to **System addresses** via LookUp Table (LUT)

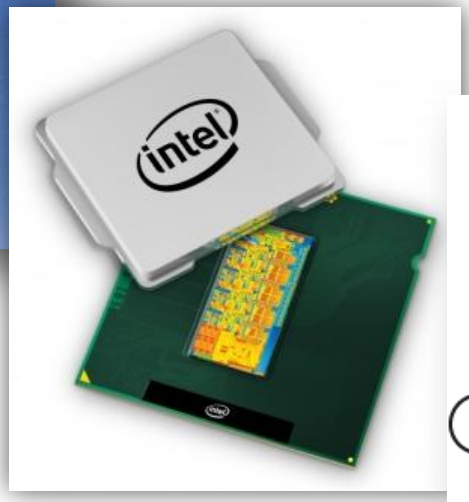


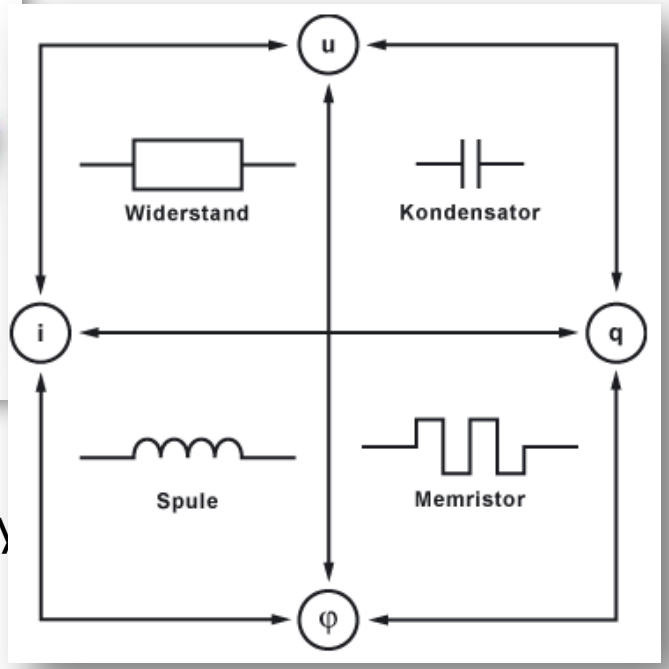
- No tile-local memory
  - Memory accesses via interconnection network
- 8-bit LUT index translates to:
  - 1-bit bypass
  - 8-bit route (msg tile)
  - 3-bit destination (mem ctrl)
  - 10-bit address extension

➢ Up to 34 bit (16GB) accessible per memory controller

Memory Cubes, Memristors, …







Computational Logic in the Memory

Seminar Overview

Lecture type: Project seminar

Team size: 1-3 students

Recommended:

- experience with Java or C++
- Lecture: Parallel Programming Concepts
  http://www.dcl.hpi.uni-potsdam.de/teaching/parProg/

Vertiefungsgebiete (SO2004): Systems Architecture, Information Systems, Network & Service Computing, Mobile & Embedded Systems, Enterprise Systems Technology
Vertiefungsgebiete (SO2010): ITSE, OSIS

Seminar Outline

Block 1: Introduction

- Introduction to project topics

- Parallel Programming Concepts Overview
- Multi-Agent Systems and Concurrency
- GPU Computing Hands-On

- Project Assignments, Discussion about success criteria

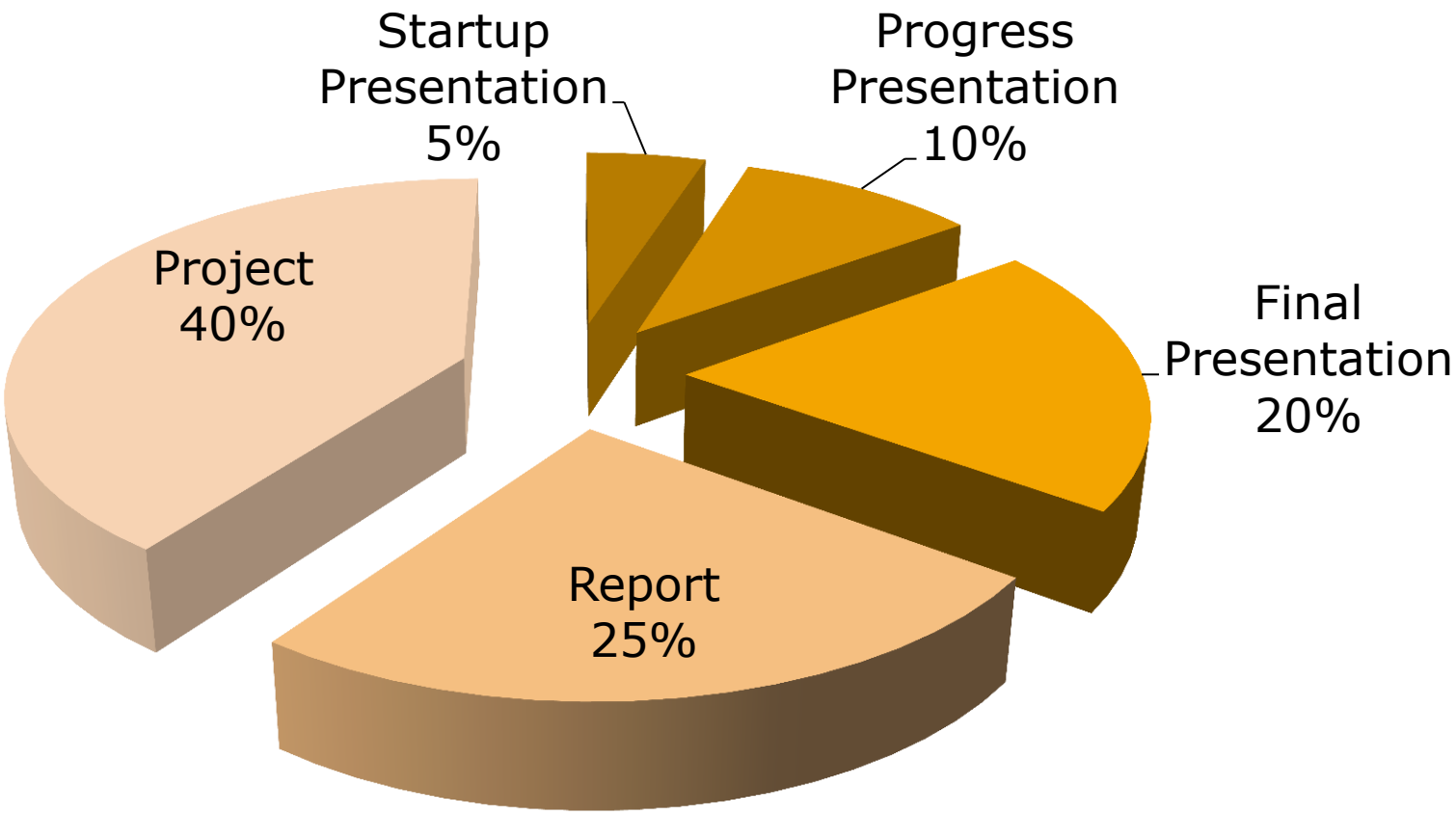
Seminar Outline

Block 2: Project Phase

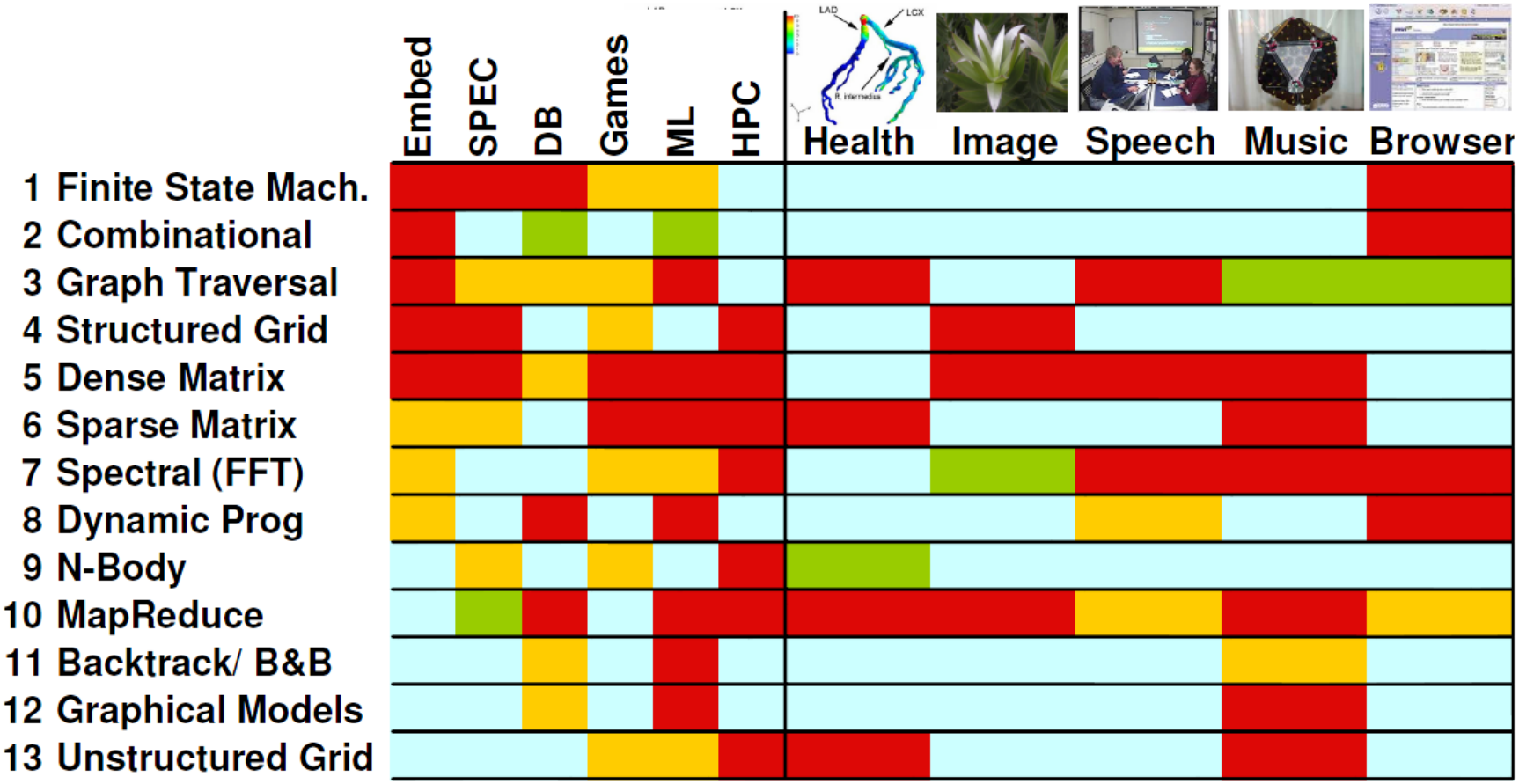
- Time for the teams to work on the projects.
  - Consulting hours at seminar time

- Three presentations per team:
  - Startup presentation
    - problem domain, problem, possible approaches
  - Progress presentation
    - selected approaches, achievements and challenges
  - Final presentation
    - solution, evaluation

Grading


Startup Presentation 5%
Progress Presentation 10%
Final Presentation 20%
Report 25%
Project 40%

Berkeley Dwarfs



Dwarf Popularity: Red = Hot; Blue = Cold

Possible Projects

Linear Algebra

Fast-Fourier-Transformations

Nqueens, Sudoku, Wator, …

Sorting Algorithms

Encryption

XML Parsing

Regular Expression Parsing

Monte Carlo

Fractals

Fluids

Ray Tracing

Statistics (PCA)

NBody

Molecular Modeling

Logic Simulation

Compression

Anti-Virus Engine

Image Processing

Speech recognition

Hidden Markov Models

Graphs

Possible Projects Mine

NAS Parallel Benchmarks

SHOC

Rodinia

PARSEC

HPC Challenge

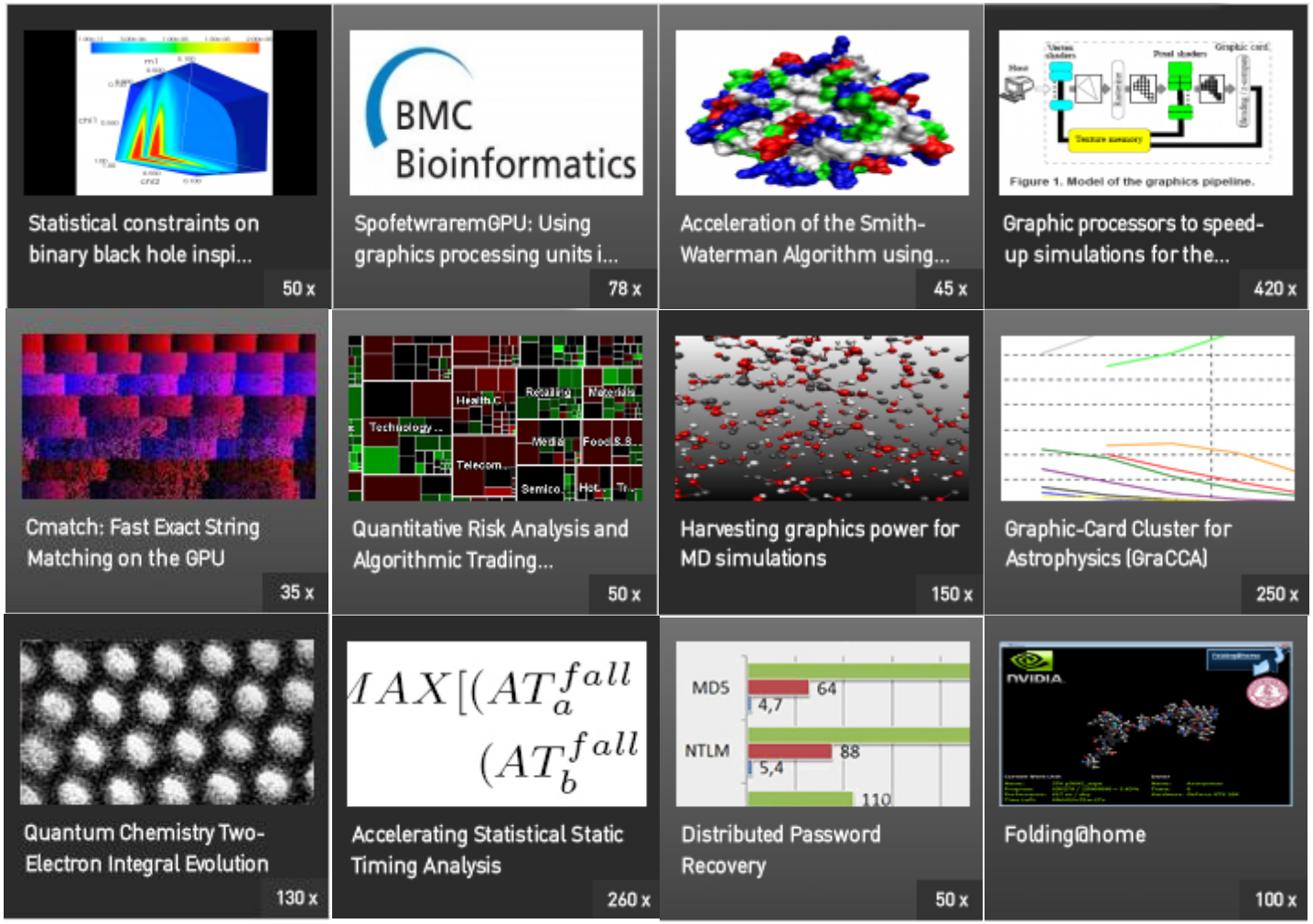
PLASMA

Paraboil Benchmark suite

Alpbench, Biobench, Parkbench, Mediabench, Minebench, Bioparallel

Pjbench

Possible Projects Mine



http://www.nvidia.com/object/cuda_apps_flash_new.html
http://www.nvidia.com/object/tesla_testimonials.html

Special Focus: Performance Optimization

Language: CUDA, OpenCL, X10, Java (Aparapi)

Course of Action

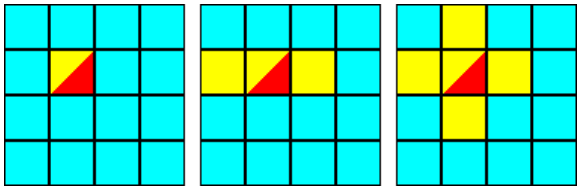
- Start Simple
- Identify Bottleneck / Optimization strategy
- Apply Performance Optimization

Please record for all versions for the final report:

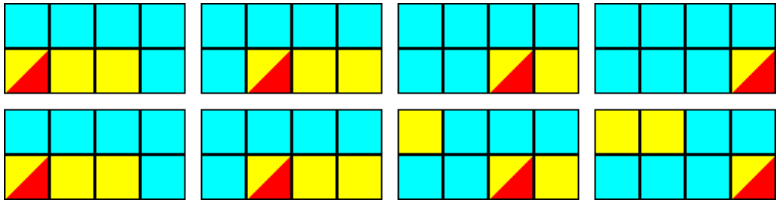
- Data Access Patterns of the Algorithm
- Performance Optimization Steps
- Evaluation of Performance Improvements

The Hybrid Parallel Project

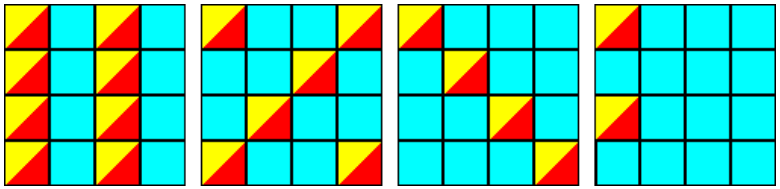
Access to Neighbors:
None, One, Two-Dimensional



Access to Neighbors: Simple vs. Ring



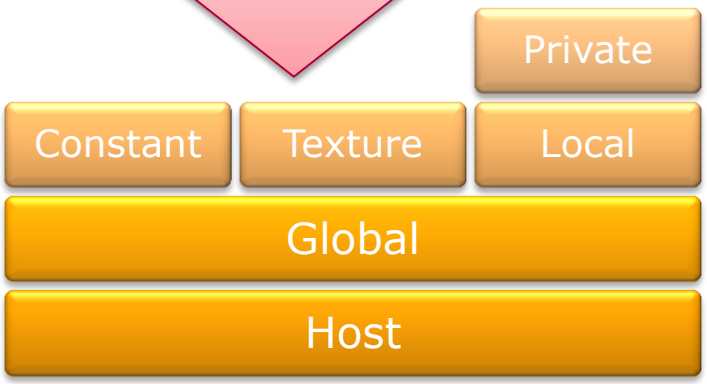
Strided Access: 1, 2, 4, 8



declare

[Pattern], [Access], [Frequency], [Stride], [Neighbors], [Borders]

map



Project ideas for Concurrent Multi-agent Systems

Cycles of War

- Multi-agent based strategy for dominating the universe ☺
- Game programing using *concurrent agents*, and perhaps some winning strategies developed in *Game Theory*

Multi-agent based Simulation (MABS)

- Mathematical models can get too complicated at times
- MABS gives us the possibility to utilize *emergence* to find possible solutions

Project ideas for Concurrent Multi-agent Systems … contd.

Agent evolution

- Using *Genetic Algorithms/Genetic Programming* to simulate an agent's DNA, and let the agent colony *evolve* to achieve some objective
- The objective does not *have* to be reproduction … it can be any useful *objective function*

Artificial Neural Networks (ANN), Genetic Algorithms (GA) and GPUs

- Metric-based learning in ANNs
- *Machine Learning* meets evolution ☺

Lehrveranstaltungen Master

Sommersemester 2012 (Vorlesungszeitr. 10.04.-14.07.2012)

Stand: 11.04.2012

Trends und Konzepte in der Softwareindustrie *Termin?* Prof. Plattner HS 3

Einführung in das Design Thinking *vor. 30.07. bis 3.08. oder 6. bis 10.08.2012* Weinberg/Nicolai D-School

Advanced Modularity Hirschfeld 26. bis 30.03.(!) u. 2.04.2012

Mainframe Computing Polze/Naumann 26. bis 30.03.(!)2012 HSG u. Seminarräume Haus A-B-C

Requirements Engin.: Elicitation + Negotiation Giese/Gabryslak *Vorbesprechung 12.04., 15:15, A-2.1* Weitere Termine s. Website

	Mo	Di	Mi	Do	(Do/)Fr(/Sa)
9:00					
10:00	**Business Process Compliance** Weske/Kunze A-2.1 **Unternehmensgründung im IT-Sektor** Hölzle H-2.57	**Sem. Geovis.-Verfahr.** Döllner/Richter H-2.57 (entfällt 10.04.!) **Information Integration** Naumann HS 3 **Web-based Software Devel. ...** Hirschfeld/Lincke A-2.1 **Trends und Konzepte... (P/S)** Plattner/Krüger/Müller SNB-E.9/10	**Visualisierung** Döllner/Lehmann/Schmechel/Buschm. H-2.57 (11.04. HS3) **Virtualis. +Cl.-Co.** Meinel/Schnjakin/Dawoud/Takouna/Willems A-2.2 **Trends u. Konzepte ... (P/S)** Plattner/Krüger/Müller SNB-E.9/10 **IT-Entrepren.-ship II** Westphal A-2.1	**Data-Structures for In-Memory...** Plattner V-2.16 **Natural Language Processing** Naumann/Momtazi H-E.52 **Akzeptanz-or. Programm.** Hirschfeld/Appeltauer/Perscheid/Taeumel A-2.2	**Blockveranstaltungen** **Persönlichkeit und Selbstmanagement** Dr. Michaela Schumacher 6. bis 8.08.2012 (Mo 9:30-18:30; Di 9:00-18:30; Mi 9:00-14:00) H-2.57
11:00	**IT-Fallstudien** Zorn und ext. Dozenten HS 3 **Semantic Multimedia** Sack/Waltelotis/Knuth/Wolf A-2.2	**System-technische Grundlagen der Regelungs...** Wollowski H-E.52 **Human Computer Interaction Research** Baudisch H-2.57 **Semantic Multimedia** Sack/Waltelotis/Knuth/Wolf A-2.2	**Komplexitätstheorie** Meinel HS 2 **Process Repositories** Weske HS 3	**Komplexitätstheorie** Meinel HS 2 **Obj.-or. Enterpr. Applic ...** Plattner/Lorenz/Müller SNB-E.9/10 **PKI & Sicherh.-stand. i. d. Cloud** Meinel/Margraf/Schnjakin A-2.1 **Process Repositories** Weske A-2.2	**Konflikt- und Kommunikationsmanagement** Dr. Michaela Schumacher 9. bis 11.08.2012 (Do 9:30-18:30; Fr 9:00-18:30; Sa 9:00-14:00) H-2.57
12:00	**D-School Advanced Track**	**D-School Basic Track**		**D-School Advanced Track**	**D-School Basic Track**
13:00					**Führungskompetenz** Michael Karl Heidemann, Eugen Unger *13.04./18.05./8.06./22.06./29.06./6.07./13.07.2012 jeweils 9:15-16:45* A-2.2
14:00	**IT-Fallstudien** Zorn und ext. Dozenten HS 3 **System-technische Grundlagen der Regelungs...** Wollowski H-E.52	**Web-b. Softw. Devel. Envir.** Hirschfeld/Lincke A-2.2 **Dependable Systems** Tröger HS 3 **Übung Komplexitätsth.** Meinel/Otten H-E.52 **Unternl.-Gründ. im IT-Sektor** Hölzle H-2.57 (entfällt 10.04.)	**IPv6 Security Aspects** Meinel/Al-Sadeh/Rafiee/Santos HS 3 **Dependable Systems** Tröger HS 1 **Fachspez. Englisch (Level 3)** Lüer A-2.1	**Human Computer Interaction Research** Baudisch H-E.52 **Global Team-Based ...** Plattner, Kowark, Krüger SNB-E.9/10 **Seminar Software-analyse-verfahren** Döllner/Trümper/Schmechel A-1.1	**Business Etikette – HPI Charm School** Dr. Timm Krohn, Imme Vogelsang 4.05./11.05./1.u.2.06./8.06./6.07.2012 (Fr 10:00-13:00; Sa 09:00-17:00) A-1.1
15:00					
16:00	**Virtual.+ Cloud-C.** Meinel/Schnjakin/Dawoud/Takouna/Willems A-1.2 **Data-Mining + Probab. Reasoning** Kasneci A-2.2 **Visualisierung** Döllner/Lehmann/Schmechel/Buschmann H-2.57 **Exotic Methods in Parall. Comp.** Tröger/Feinbube/Khalid H-E.52	**HCI Project Seminar on Interaction, Depth ...** Baudisch H-2.57 (10.04. HS 3) **Algorithms for Pattern Mining** Naumann H-E.52 **Programming Lang. Concepts ...** Hirschfeld/Steinert/Taeumel/Perscheid A-2.2	**Seminar d. Forschungskollegs** Polze H-2.57 (11.04. HS 3) **Adv. Softw. Engineer. for Embedded ...** Giese/Wätzold H-2.58 (nur 11.04.)	**HPI-Kolloquium** HS 1	**~~Personal Leadership Skills~~** Dr. Rolf Specht 14. bis 17.08.2012 jeweils 9:00-12:30 u. 13:30-17:00 A-1.1
17:00	**Soft-Skills-Kolloquium** Krohn HS 1	**Management Essentials** Wagner A-2.1 **IPv6 Security Aspects** Meinel/Al-Sadeh/Rafiee/Santos HS 3 **Adv. Software Engin. f. Emb. ...** Giese/Wätzold H-2.58 (nur 10.04.) **Seminar Softw.-analyse-verfahr.** Döllner/Trümper/Schmechel H-E.52	**Seminar Geovisualisierungsverfahren** Döllner/Richter H-2.57 **Exercise: Data-Min. and Probabilistic ...** Kasneci A-1.1 *14-tägl/ch*		**Überzeugend Präsentieren** René Borbonus 11.u.12.05./1.06./7.07.2012 jeweils 9:15-16:45 A-2.1
18:00					
19:00					

Seminar Schedule: Block 1

Schedule	Mo	Tu	We	Th	Fr
First Meeting / Dog & Pony Show Projects Teaser (Introduction to Parallel Computing by Frank)	**16.04.2012**	**16.04.2012**	**16.04.2012**	**16.04.2012**	**16.04.2012**
Introduction to Parallel Computing by Frank (GPUs by Frank)	**23.04.2012**	**24.04.2012**	**18.04.2012**	**19.04.2012**	**20.04.2012 (Peter Tröger)**
FREE	30.04.2012	01.05.2012 Maifeiertag	25.04.2012	26.04.2012	27.04.2012
Agents by Fahad	**07.05.2012**	**08.05.2012**	**02.05.2012**	**03.05.2012**	**04.05.2012**
Agents by Fahad Wish for Projects	**14.05.2012**	**15.05.2012**	**09.05.2012**	**10.05.2012**	**11.05.2012**
FREE				17.05.2012 Himmelfahrt	
GPUs by Frank Project Assignments Discussion about success criteria	**21.05.2012**	**22.05.2012**	**16.05.2012**	**24.05.2012**	**18.05.2012**

Seminar Schedule: Block 2

Schedule	Mo	Tu	We	Th	Fr
Work on Projects Consulting hours	28.05.2012 Pfingstmontag	29.05.2012	23.05.2012		25.05.2012
Initial Presentations **Deadline for Enrollment**	**04.06.2012**	**05.06.2012**	**30.05.2012**	**31.05.2012**	**01.06.2012**
Work on Projects Consulting hours	11.06.2012	12.06.2012	06.06.2012 13.06.2012	07.06.2012 14.06.2012 21.06.2012	08.06.2012 15.06.2012
Progress Presentations	**18.06.2012**	**19.06.2012**	**20.06.2012**	**28.06.2012**	**22.06.2012**
Work on Projects Consulting hours	25.06.2012 02.07.2012	26.06.2012 03.07.2012	27.06.2012 04.07.2012	05.07.2012	29.06.2012 06.07.2012
Final Presentations	**09.07.2012**	**10.07.2012**	**11.07.2012**	**12.07.2012**	**13.07.2012**

Based on:

Lecture: Parallel Programming Concepts
http://www.dcl.hpi.uni-potsdam.de/teaching/parProg/