



# TDDD56 Multicore and GPU Programming

Christoph Kessler

IDA  
Linköping university  
Sweden

<http://www.ida.liu.se/~chrke/>

2014



## Staff 2014

- **Christoph Kessler**, IDA [christoph.kessler \(at\) liu. se](mailto:christoph.kessler@liu.se)
  - Organization, most lectures, examiner
- **Ingemar Ragnemalm**, ISY [ingis \(at\) isy. liu. se](mailto:ingis@isy.liu.se)
  - Lectures on GPU programming, GPU labs
- **Nicolas Melot**, IDA [nicolas.melot \(at\) liu. se](mailto:nicolas.melot@liu.se)
  - Course assistant, lessons, CPU labs
- **Lu Li**, IDA [lu.li \(at\) liu. se](mailto:lu.li@liu.se)
  - Lab assistant CPU+GPU labs
- **Carita Lilja**, IDA [carita.lilja \(at\) liu. se](mailto:carita.lilja@liu.se)  
(before january: Åsa Kärrman, [asa.karrman \(at\) liu. se](mailto:asa.karrman@liu.se))
  - Course secretary (Ladok reporting)
- **Tommy Färnqvist**, IDA [tommy.farnqvist \(at\) liu. se](mailto:tommy.farnqvist@liu.se)
  - Director of undergraduate studies

2



## Are you registered?

- Currently, the course is full.
- Non-registered students please contact me by email asap. for enqueueing on the **waiting list**.
  - At the end of this week (webreg deadline on friday) we will know how many spare spots we have
  - Acceptance in FIFO order as space will be available, then you can register (course + webreg)
  - No guarantee, unfortunately
- Lab registration and participation is not possible for non-registered students.
  - But attending the lectures and lessons is always possible

3



## Course Moments

- Lectures
- Lessons (mandatory for the labs)
- Labs (mandatory presence)
- Credits:
  - Written exam, 3 hp
  - Lab series attended and completed by deadlines, 3 hp
    - ▶ No guarantee for completing / correcting labs after the deadlines

4

\* Similar as in TDDC78



## Lectures (1)

- **Lecture 1:** Organization, Overview. Motivation, Multicore architectural concepts and trends. (CK)
- **Lecture 2:** Parallel programming with threads and tasks. (CK)
- **Lesson 1:** How to measure and visualize performance of parallel programs. CPU lab introduction. (NM)
- **Lecture 3:** Shared memory architecture concepts and performance issues\*. (CK)
- **Lecture 4:** Non-blocking synchronization. (CK)
- **Lecture 5-6:** Theory: Design and analysis of parallel algorithms\* (1.5 slots). (CK)
- **Lecture 6-7:** Parallel sorting algorithms (1.5 slots). (CK, guest)
- **Lesson 2:** Introduction to Lab 3 (non-blocking synchronization). Selected theory exercises. (NM)  
*Please solve suggested exercises in advance to be prepared.*

5



## Lectures (2)

- ...
- **Lecture 8:** Parallelization of sequential programs\*. (CK)  
*Mid-term evaluation.*
  - **Lecture 9:** GPU architecture and trends (IR)
  - **Lecture 10:** Introduction to CUDA programming. (IR)
  - **Lecture 11:** CUDA programming. GPU lab introduction. (IR)
  - **Lecture 12:** Sorting on GPU. Advanced CUDA issues. (IR)
  - **Lecture 13:** Introduction to OpenCL. (IR)
  - **Lesson 3:** OpenCL. Shader programming. Exercises. (IR)
  - **Lecture 14:** High-level Parallel Programming with Skeletons\* and Components. Autotuning\* (CK)
  - **Lecture 15:** Advanced issues

6

## Lab Series (1)



**CPU-labs** (week 46-48, Nicolas Melot / Lu Li)

- Lab 1: Load balancing (warm-up)
- Lab 2: Parallel sorting
- Lab 3: Nonblocking synchronization

**GPU-labs** (week 49-51, Lu Li / Ingemar Ragnemalm)

- Lab 4: CUDA 1
- Lab 5: CUDA 2
- Lab 6: OpenCL and Shader programming

7

## Lab Series (2)



- 3 groups in 2 passes (mostly A || B ; C )
  - **Grupp\_A** (32 students)
    - ▶ Nicolas Melot / Lu Li, in ISY Southfork
  - **Grupp\_B** (16 students)
    - ▶ Lu Li / Ingemar Ragnemalm, in IDA Multicore Lab
  - **Grupp\_C** (16 students)
    - ▶ Nicolas Melot / Lu Li, in IDA Multicore Lab
- Work in pairs. No exceptions, sorry – the course is full!
- Sign up in **webreg** ([www.ida.liu.se/webreg](http://www.ida.liu.se/webreg)) by **7/11/2014**
  - Or you will lose your lab spot to someone on the waiting list

8

## Lab Series (3)



- **Mandatory presence!** (ISY-style labs)
- Rooms are reserved for our course during scheduled lab hours
  - **Southfork** (Group A):  
No guarantees outside scheduled lab hours. Open 08-17.
  - **Multicore Lab** (Groups B, C):  
Locked outside supervised lab hours.
- Demonstration / lab reports to lab assistant by the deadlines
  - CPU labs: **03/12/2014**
  - GPU labs: **17 resp. 18/12/2014** (last lab session)
- Be well-prepared!  
Supervised lab time is too costly for reading the instructions ...
- **No copying!**

9

## Parallel Sorting Contest



- Optional
- Engineer the fastest parallel sorting implementation on the lab computers
  - Category Konrad Zuse (Multicore lab)
  - Category Southfork
- Benchmark data sets and further instructions provided by Nicolas
- Current high-score may be displayed on the course homepage
- 2 awards to be presented in the last lecture



10

## Course material and WWW homepage



- All information available on the course homepage:  
[www.ida.liu.se/~TDDD56](http://www.ida.liu.se/~TDDD56)
- Some slide sets and other material require login/password
  - Sent out to registered participants + waiting list
  - Please keep it secret
- Lab assignments on the course homepage

11

## Introductory Literature (Selection)



If you already attended TDDC78, you need no book on the general / CPU part.

Otherwise, one of the following introductory books might be useful (available in the TekNat library as refcopy and for loan):

- C. Lin, L. Snyder: *Principles of Parallel Programming*. Addison Wesley, 2008.  
(general introduction; Pthreads)
- B. Wilkinson, M. Allen: *Parallel Programming*, 2e. Prentice Hall, 2005.  
(general introduction; pthreads, OpenMP, MPI)



12

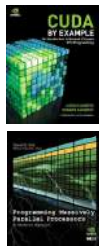
## GPU Programming Literature



Focus on CUDA. One of the following books might be useful:

- J. Sanders, E. Kandrot: *CUDA by example*. Addison-Wesley, 2011. (recommended)
- David B. Kirk and Wen-mei W. Hwu: *Programming Massively Parallel Processors: A Hands-on Approach*. Morgan Kaufmann, 2010. Second edition 2012.

Available in the TekNat library



13

## Further Reading



- M. Herlihy, N. Shavit: *The Art of Multiprocessor Programming*. Morgan Kaufmann, 2008. (threads; nonblocking synchronization)
- A. Grama, G. Karypis, V. Kumar, A. Gupta: *Introduction to Parallel Computing, 2nd Edition*. Addison-Wesley, 2003. (design and analysis of parallel algorithms)
- ...

See the course homepage for further references

- Available in TekNat library

- On-line references on the course homepage



14

## Another Master-Level Course ...



### TDDC78 Programming of Parallel Computers, 6hp

- VT2 (march – may) every year
- Topics include:
  - Parallel computer architecture concepts, esp. clusters
  - Parallel algorithms for High-Performance Computing
  - Parallel thread programming with OpenMP (Labs)
  - Message passing programming of clusters with MPI (Labs)
  - Tools for performance analysis (Labs)
- Labs on Swedens currently largest (academic) supercomputer, at NSC
- A good complement of TDDD56



15