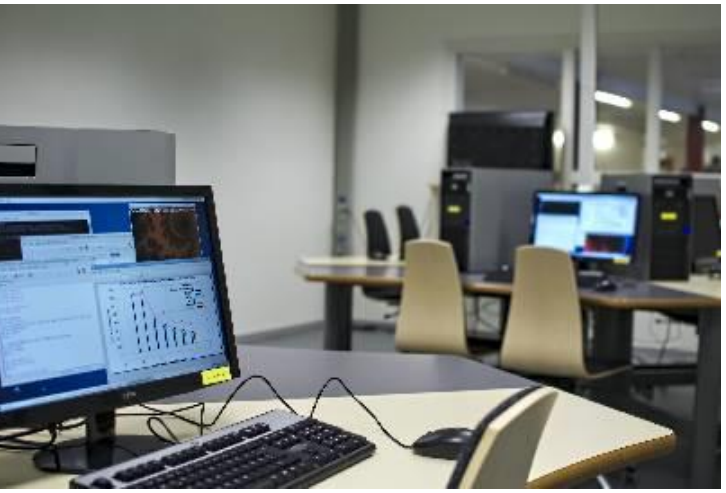
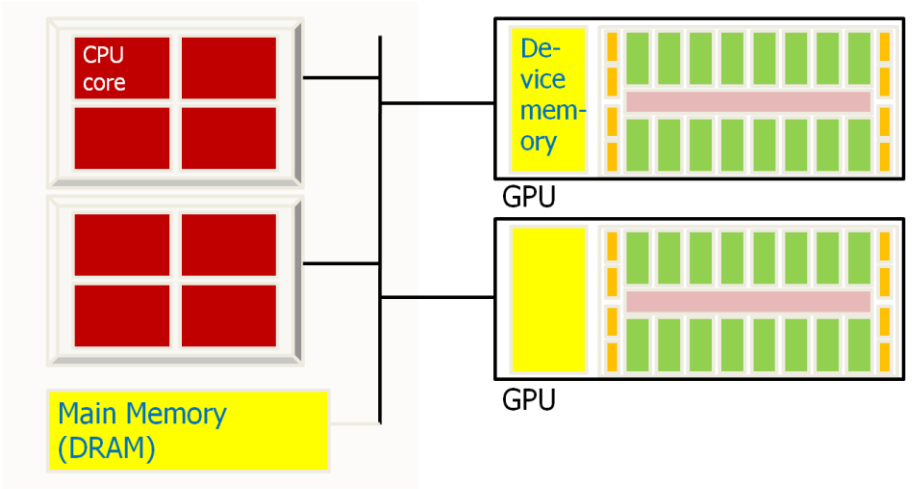




TDDD56
Multicore and GPU Programming

Christoph Kessler

IDA
Linköping University
Sweden

2022

LINKÖPING UNIVERSITY

Staff 2022

- **Christoph Kessler**, IDA christoph.kessler (at) liu. se
  - Organization, most lectures, examinator
- **Ingemar Ragnemalm**, ISY ingemar.ragnemalm (at) liu. se
  - Lectures on GPU programming, GPU labs
- **August Ernstsson**, IDA august.ernstsson (at) liu. se
  - Course assistant, lessons, CPU + GPU labs
- **Sehrish Qummar**, IDA
  - Additional assistant in Labs 1 and 3

- **Elena Larsson**, IDA elena.larsson (at) liu. se
  - Course secretary (Ladok reporting)
- **Martin Sjölund**, IDA martin.sjolund (at) liu. se
  - Director of undergraduate studies

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

Lectures (1)

- **Lecture 1:** Organization, Overview.
  Motivation, Multicore architectural concepts and trends (CK)
- **Lecture 2:** Shared memory architecture concepts***** (CK)
- **Lecture 3a:** Parallel programming with threads (CK)
- **Lecture 4:** Non-blocking synchronization (CK)
- **Lecture 3b**: Parallel programming with tasks (CK, 45min)
  Lesson 1: CPU lab 1+2 introduction (AE, 45min)
- **Lectures 5-6:** Design and analysis of parallel algorithms***** (CK)
- **Lecture 7:** Parallel sorting algorithms (CK)
- **Lecture 8**: Parallel algorithmic design patterns and skeletons. (CK, 45min)
  Lesson 2: Introduction to skeleton programming in SkePU / Lab 3 (AE, 45min)

Lectures (2)

…

- **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)
- **Lesson 4:** Selected theory exercises. (AE)
  Please solve suggested exercises in advance to be prepared.
- **Lecture 14:** Optimization and parallelization of loop-based sequential programs*. (CK)

Lab Series (1)

CPU-labs (week 45, 46, 47)

- Lab 1: Load balancing (warm-up)
- Lab 2: Nonblocking synchronization
- Lab 3: Skeleton programming; Median filtering

GPU-labs (week 48, 49, 50)

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

Lab Series (2)

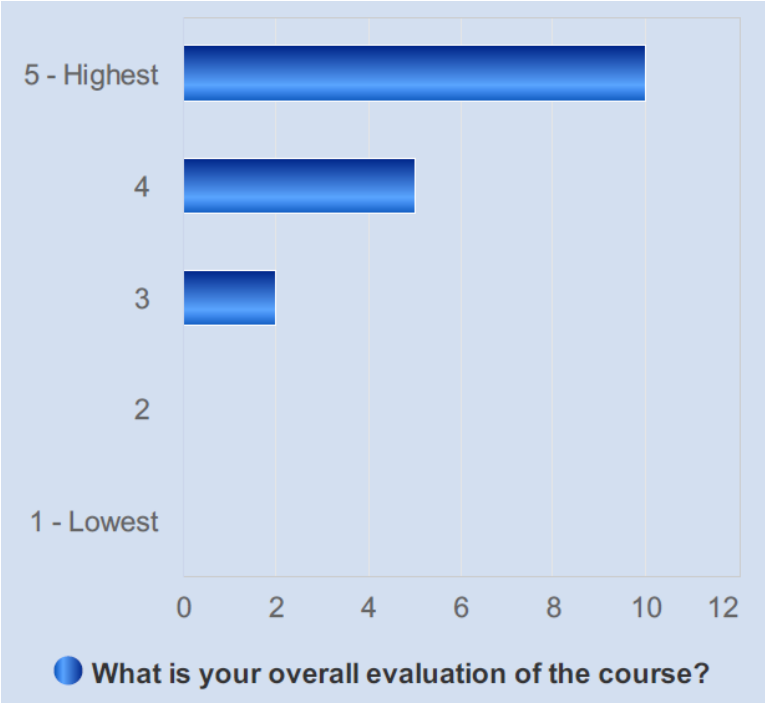
- 2 groups in 2 passes (A, B)
  - **Group A** (~24 students)
    - v45,46,47: August Ernstsson
    - v48,49,50: Ingemar Ragnemalm
  - **Group B** (~24 students)
    - v46-50: August Ernstsson
- We use the computers in ***Olympen*** (B-house, entry 25, upper floor)
- Work in **pairs**.
  - No singletons, please
- Sign up in **webreg** (www.ida.liu.se/webreg) by **this friday**
  - We reserve the right to compact and balance groups

Lab Series (3)

- **Mandatory presence!** **(ISY-style labs)**
- The lab room (Olympen) is reserved (and paid!) for our course during scheduled lab hours.
  - No guarantees of access/availability of Olympen / its computers outside scheduled lab hours.
- Demonstration / lab reports to lab assistant by the **deadlines**
  - CPU labs: last CPU lab session **24/11** resp. **25/11/2022** (soft), latest **14/12** resp. **16/12/2022 10:00** (hard)
  - GPU labs: last GPU lab session, **14/12** resp. **16/12/2022**
- Be well-prepared!
  Supervised lab time is too costly for reading the instructions …
- **No copying!**

Changes Since 2021

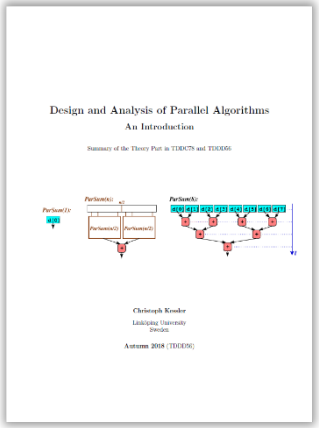
- No major changes in contents / structure
  - The course evaluation was very good (4.47, 17 of 47)



- Return to physical lectures and lessons

Course material and homepage

- All information available on the **course homepage:** www.ida.liu.se/~TDDD56
  - We do *NOT* use LISAM!
- **Course books / compendia**:
  - C. Kessler: ***Design and Analysis of Parallel Algorithms: An Introduction***. Compendium, (c) 2020.
    - PDF available for registered course participants. Not for general distribution.
    - Covers the 3 lectures on analysis of parallel algorithms and on parallel sorting, and the patterns introduction.
  - I. Ragnemalm: ***Attack in Packs***. Compendium, (c) 2018.
    - PDF available for registered course participants. Not for general distribution.
    - Covers the GPU lectures.
- Some slide sets and other material require **login/password**
  - Sent out to registered participants + guest participants
  - Please keep it secret
- **Lab assignments** on the course homepage

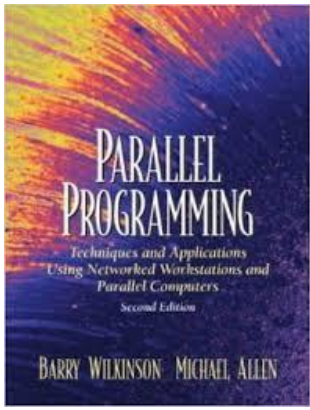


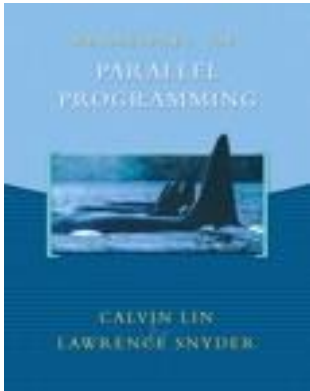
Introductory Literature (Selection)

If you already attended TDDC78, you need no other textbook on the general parallel computing / CPU part.

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

- B. Wilkinson, M. Allen:
  Parallel Programming, 2e.
  Prentice Hall, 2005.
  (general introduction; **Pthreads**, OpenMP, MPI;
  also used in TDDC78)
- C. Lin, L. Snyder:
  Principles of Parallel Programming.
  Addison Wesley, 2008.
  (general introduction; **Pthreads**)
  - Errata for the first printing:
    https://www.cs.utexas.edu/~lin/errata.html





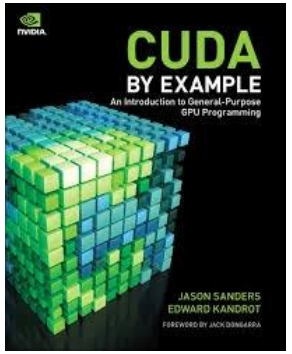
GPU Programming Literature

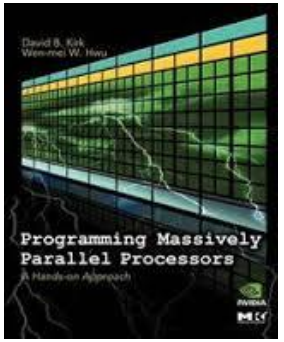
Focus on CUDA.

One of the following books might be useful:

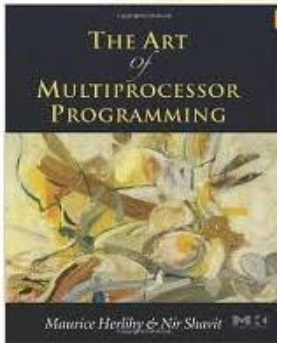
- J. Sanders, E. Kandrot: *CUDA by example*. Addison-Wesley, 2011. (recommended)
- David B. Kirk and Wen-mei W. Hwu: *Programming Massively Parallel Processors: A Hands-on Approach.* Morgan Kaufmann, 2010. Second edition 2012.

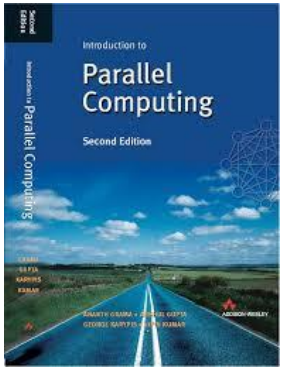
Available in the LiU library





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 the LiU library

- **On-line references** on the course homepage

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 largest (academic) supercomputer (or equivalent), at NSC
- A good complement of TDDD56