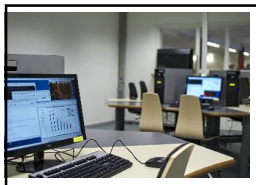

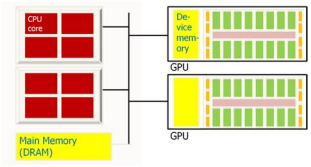

TDDD56
Multicore and GPU Programming

Christoph Kessler

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Linköping University
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2017

LINKÖPING UNIVERSITY

Staff 2017

- **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 labs
- **Lu Li**, IDA lu.li (at) liu. se
  - Lab assistant CPU+GPU labs
- **N.N.**, IDA adm-gu (at) ida. liu. se
  - Course secretary (Ladok reporting)
- **Ahmed Rezine**, IDA ahmed.rezine (at) liu. se
  - Director of undergraduate studies

Are you registered on TDDD56?

- Currently, there are still some free spots (limit: 64).
- Non-registered students please sign up asap.
  - No labs nor exam correction without course registration
    - Exception: PhD students who got my approval for taking the course
  - Attending lectures and lessons is always possible
- Lab registration via webreg is not possible for non-course-registered students.
  - PhD students please contact the course assistant directly for registration in webreg

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)

* Similar as in TDDC78

- **Lecture 1:** Organization, Overview. Motivation, Multicore architectural concepts and trends. (CK)
- **Lecture 2:** Shared memory architecture concepts and performance issues*. (CK)
- **Lecture 3:** Parallel programming with threads and tasks. (CK)
- **Lecture 3** (cont.) (CK, ~45min)
  Lesson 1: CPU lab introduction (AE, ~45min)
- **Lecture 4:** Non-blocking synchronization. (CK)
- **Lectures 5-6:** Theory: Design and analysis of parallel algorithms*. Sorting revisited. (CK)
- **Lecture 7:** Parallel sorting algorithms. (CK)
  Mid-term evaluation.
- **Lecture 8**: Parallel algorithmic design patterns and skeletons (CK).
  Lesson 2: Introduction to skeleton programming in SkePU (AE)

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:** Parallelization of sequential programs*. Multicore Programming Contest Awards. Outlook. (CK)

Lab Series (1)

CPU-labs (week 45, 46, 47 - August Ernstsson, Lu Li)

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

GPU-labs (week 48, 49, 50 – Lu Li, Ingemar Ragnemalm)

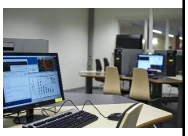
- Lab 4: CUDA 1
- Lab 5: CUDA 2
- Lab 6: OpenCL and Shader programming

Lab Series (2)

- 3 groups in 2 passes (A || B ; C)
  - **Grupp_A** (32 students) in ISY Southfork
    - August Ernstsson (v45-47) + Lu Li (v48-50)
  - **Grupp_B** (16 students) in IDA Multicore Lab
    - Lu Li (v45-47) + Ingemar Ragnemalm (v48-50),
  - **Grupp_C** (16 students) in IDA Multicore Lab
    - August Ernstsson (v45-47) + Lu Li (v48-50)
- Work in pairs. Singleton teams only in exceptional cases.
- Sign up in **webreg** (www.ida.liu.se/webreg) by **this friday**
  - We reserve the right to compact and balance lab groups

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: 23/11/2017 (soft), **14/12/2017** (hard)
  - GPU labs: **13/12 resp. 14/12/2017** (last lab session)
- Be well-prepared!
  Supervised lab time is too costly for reading the instructions …
- **No copying!**

Multicore Programming Contest

- Optional
  - We encourage participation if you are on time and do well on the CPU/GPU sorting labs
- Engineer the fastest parallel sorting implementation on the lab computers
  - Category Multicore lab
  - Category Southfork
- Benchmark data sets and further instructions provided by August
- 2 awards to be presented in the last lecture

Course material and WWW homepage

- All information available on the course homepage:
  www.ida.liu.se/~TDDD56
- 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 book on the general / CPU part.

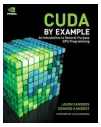
Otherwise, one of the following introductory books might be useful (available in the TekNat library as refcopy and for loan):

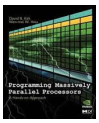
- B. Wilkinson, M. Allen:
  Parallel Programming, 2e.
  Prentice Hall, 2005.
  (general introduction; pthreads, OpenMP, MPI; also used in TDDC78)
- C. Lin, L. Snyder:
  Principles of Parallel Programming.
  Addison Wesley, 2008.
  (general introduction; Pthreads)

GPU Programming Literature

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

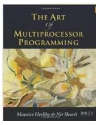
- J. Sanders, E. Kandrot: *CUDA by example*. Addison-Wesley, 2011. (recommended)
- David B. Kirk and Wen-mei W. Hwu: *Programming Massively Parallel Processors: A Hands-on Approach*. Morgan Kaufmann, 2010. Second edition 2012.





Available in the TekNat library

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

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 (new 2018) (academic) supercomputer, at NSC
- A good complement of TDDD56