Iterative Linear Solvers and Parallelization @ HLRS

Dr. Rolf Rabenseifner, Prof. Dr. Andreas Meister

University of Stuttgart
High-Performance Computing-Center Stuttgart (HLRS)
www.hlrs.de

Iterative Linear Solvers & Parallelization @HLRS – 1st day

Content

MPI on beginners' level 

[Tobias Haas and Rolf Rabenseifner]

1. MPI Overview
2. Process model and language bindings
3. Messages and point-to-point communication
4. Nonblocking communication

File: mpi_3.1_rab.pdf

Schedule

08:45 Login to ZOOM (hybrid course only)
(and establishing the break-out rooms)

09:00 Welcome

09:05 Lectures and exercises on MPI
(including some breaks)

12:30 Lunch break

13:45 Lectures and exercises on MPI
(including some breaks)

16:45 End

After the course:

S-Bahn to the city (self-paying)

City sightseeing walking tour (free)

Dinner (self-paying)

Iterative Linear Solvers & Parallelization @HLRS – 2nd day

Content

Shared memory parallelization with OpenMP
[Lucienne Dettki and Rolf Rabenseifner]

- Overview
- Execution model
- Worksharing directives
- Worksharing – continued (Exe 2b)
- Data environment
- Heat example (homework)
- Summary
- Pitfalls
- Q&A

File: **openmp-intro13.pdf**

Schedule

08:45 Login to ZOOM (hybrid course only)
09:00 Lectures and exercises on OpenMP (including some breaks)
12:30 Lunch break
13:45 Lectures and exercises on OpenMP (including some breaks)
16:45 Final end

Iterative Linear Solvers & Parallelization @HLRS – 3rd day

Content

Iterative Solvers for Large Linear Systems
[Andreas Meister]

Files: in **Lectures_Original_Version** (with animation)
and **Lectures_Print_Version** (without animation)
and **exercises_matlab.pdf**

9:00 Introduction, Basics and Practicals (Lecture I. + Practicals)
10:00 Consistency and Convergence (Lecture I. continued)
11:00 Break
11:30 Jacobi Method (Lecture II.)
12:15 Practicals
13:00 Lunch
14:15 Gauß-Seidel Method (Lecture II. continued)
14:45 Practicals
15:15 Q+A
15:30 Break
15:45 **MPI:**
6-(1) Collective Communication 

File: **mpi_3.1_rab.pdf**
16:45 End

Schedule

08:45 Login to ZOOM (hybrid course only)
09:00 Lectures & exercises on Iterative Solvers (including some breaks)
13:00 Lunch break **[30 Minutes later!]**
14:15 Lectures & exercises on Iterative Solvers (including some breaks)
15:30 Other options on MPI
16:45 Final end

Iterative Linear Solvers & Parallelization @HLRS – 4th day

Content

Iterative Solvers for Large Linear Systems
[Andreas Meister]

9:00 Relaxation Schemes (Lecture II. continued)
10:00 Practicals
10:45 Break
11:00 Method of Steepest Descent (Lecture III.)
11:30 Practicals
12:00 Lunch
13:15 Method of Conjugate Gradients (Lecture III.)
14:15 Practicals
15:00 Q+A
15:15 Break
15:30 **MPI & OpenMP:**
Parallelization of Explicit and Implicit Solvers (talk) 
File: **parallelization_rab.pdf**
16:45 End

Schedule

08:45 Login to ZOOM (hybrid course only)
09:00 Lectures & exercises on Iterative Solvers (including some breaks)
12:00 Lunch break **[30 Minutes earlier!]**
13:15 Lectures & exercises on Iterative Solvers (including some breaks)
15:30 For MPI & OpenMP: Parallelization
16:45 Final end

Iterative Linear Solvers & Parallelization @HLRS – 5th day

Content

Iterative Solvers for Large Linear Systems
[Andreas Meister]

09:00 Introduction to Multigrid Methods (Lecture IV.)
10:00 Practicals
10:30 Break
10:45 GMRES and BICG (Lecture V.)
11:45 Practicals
12:15 Lunch
13:30 Variants of BICG (Lecture V. continued)
14:00 Practicals
14:30 Preconditioning (Lecture VI.)
15:30 Q+A
15:45 Break
16:00 **MPI:** 12. Derived datatypes (talk w/o practical)
(1) transfer any combination of typed data
File: mpi_3.1_rab.pdf 

16:30 Q+A / Feedback
16:45 End

Schedule

08:45 Login to ZOOM (hybrid course only)
09:00 Lectures & exercises on Iterative Solvers (including some breaks)
12:15 Lunch break **[15 Minutes earlier!]**
13:30 Lectures & exercises on Iterative Solvers (including some breaks)
16:00 Other options on MPI
16:30 Feedback
16:45 Final end

Organizational remarks

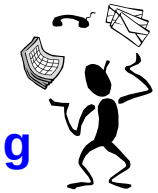
- Laptops: do not close them (otherwise all files are lost)
- Lunch: Mensa (nearest canteen / cafeteria)
- Breaks: please do **not** take any drinks or food into the seminar room
  (only empty cups are allowed for re-use in next break)
- First day: Social event
  - self paying – not included in the registration fee
  - Free tour starts immediately after the course
- Exercises
  - 
    Important: To solve the exercises please use presented slides
    and the provided .c/.f90 skeleton files
    (or in rare cases also the MPI standard)
    but no google search on the web – otherwise you are too slow
    
  - Options:
    - **Work together with your neighbor**
    - **Work for your own and discuss problems and compare results with your neighbor**
  - Please do not look at the solution before you finished this exercise,
    otherwise,
    90% of your learning outcome may be lost
    
  - When finished the **basic** exercise: **advanced exercises *versus* coffee break**

Links

- **Course-Announcements**
  - German portals:
    - www.hlrs.de/training/ (by HLRS), by JSC and LRZ.
    - Gauss Centre of Supercomputing (GCS) Event List
    - German HPC Calendar (by Gauss-Allianz & German HPC / NHR Centers) + long list with abstracts
  - European portals: HPC in Europe, CoE Training Registry, and EuroCC2 training.
- **Self-study materials**
  - https://www.hlrs.de/training/self-study-materials/
    - **Password-free: latest MPI slides & all exercises**
      - https://www.hlrs.de/training/self-study-materials/MPI-course-material
    - **With password (i.e., only for members of the HLRS email list)**
      - **MPI-Course** (2024/2023/2022) with English / German recordings (including Python)
      - **OpenMP-Course** (2023/2022) with English / German recordings
- **Standards (MPI, OpenMP)**
  - www.mpi-forum.org → MPI documents (see also errata document)
  - www.openmp.org → OpenMP Specifications
- **Practical (skeletons, solutions)**
  - https://fs.hlrs.de/projects/par/events/2025/ITER-HLRS/README.html
  - (https://fs.hlrs.de/projects/par/par_prog_ws/practical/README.html)

Summary — Iterative Linear Solver & Parallelization

- Iterative Linear Solver
- Parallel Programming:
  - MPI – **Distributed Memory Parallelisierung**
  - OpenMP – **Shared Memory Parallelisierung**
  - MPI-3.1/4.0 and OpenMP-4.0/4.5/5.0 advanced features
  - Parallelization
  - Slides + Practicals: https://fs.hlrs.de/projects/par/events/2025/ITER-HLRS/README.html
  - Further workshops and courses:
    - www.hlrs.de/training/
    - www.hlrs.de/training/self-study-materials/ **(Self-Study Materials)**



Many thanks for your interest and strong collaboration

rabenseifner@hlrs.de 0711-685-65530