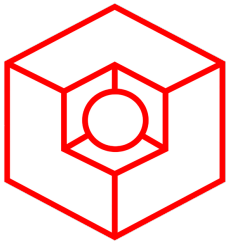


BremHLR

Kompetenzzentrum für Höchstleistungsrechnen Bremen

Parallel Programming with MPI and OpenMP

September 15 – 18, 2025

Instructors:

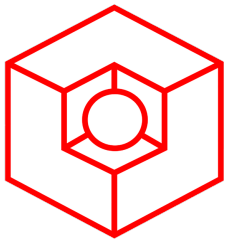
Dr. Hinnerk Stüben (University of Hamburg)

Dr. Lars Nerger (BremHLR & Alfred Wegener Institute)

Course material will be available at

http://bremhlr.uni-bremen.de/mpi-openmp-course

About us …



BremHLR
Kompetenzzentrum für Höchstleistungsrechnen Bremen

Bremen Supercomputing Competence Center

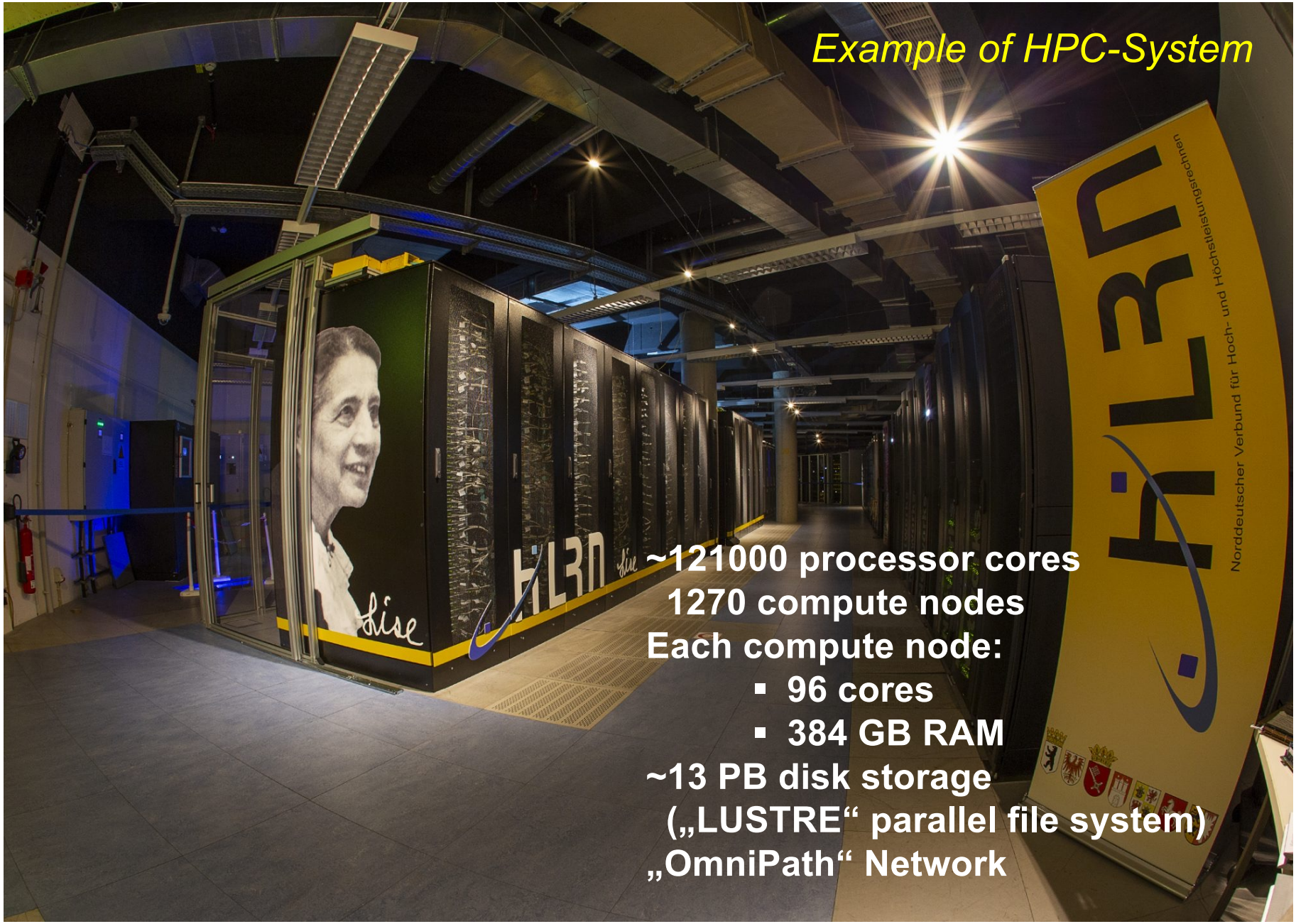
- Cooperation of 4 Universities and Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research
- We don't operate supercomputers but know well how to use them
- Support in supercomputing for researchers in the state of Bremen
- Consultants at Bremen University/ZARM, Constructor University and AWI

About us …

We work as HPC Consultants

- Provide support for using high-performance computing (HPC) systems
  - Technical issues, performance, application for compute projects
- Teaching
  - how to use HPC Systems
  - how to optimize program code for maximal performance
  - parallel programming – how to make programs usable for HPC

NHR@ZIB “Lise” in Berlin



Parallel Programming with MPI and OpenMP

Goals

- Introduce to program parallelization with focus on C and Fortran
- Use the compute power of today's multi-core processors and of supercomputers
- Go beyond starting the same program several times
- Go beyond auto-parallelization options offered by compilers

Lectures

Hands-on sessions

Parallel Programming with MPI and OpenMP

Content

- How to distribute the work of a program over several processor cores, processors or computers?
- Introduction to the two most-common parallelization standards

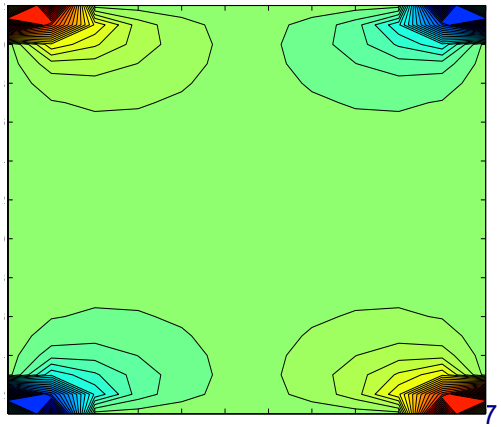
MPI	*OpenMP*
Distributed memory parallel	**Shared memory**
e.g. use a cluster of computers connected by a network	e.g. use all cores in a workstation

- Exemplify the parallelization on a physical example:

  Solution of Laplace's equation in two dimensions

$$\nabla^2 \psi = 0$$

  (e.g. electrostatic potential)



Parallel Programming with MPI and OpenMP

Schedule

- Monday: 10:15 – 12:30 / 13:30 – 17:00h
- Tuesday to Thursday:
  - 9:15 – 12:30h / 13:30 – 17:00h
  - lunch break ~12:30-13:30h
- Each block: lecture followed by exercises

Parallel Programming with MPI and OpenMP

Today

- Welcome
- Thinking Parallel I
- Laplace I: Theory
- Computer Setup
- *Exercise:* a parallel *hello world* program

- MPI – Structure of MPI programs
- MPI – Point-to-point communication
- MPI – Collective communication
- *Exercise:* programming send and receive

Parallel Programming with MPI and OpenMP

Course material

http://bremhlr.uni-bremen.de/mpi-openmp-course

(will be uploaded step-by-step during the week)

Parallel Programming with MPI and OpenMP

Tuesday

- Morning – MPI
  - Review of programming exercises
  - MPI – point-to-point communication (send and receive modes)
  - MPI – collective communication, Communicator splitting
  - MPI – Reduction operations
  - *Exercise:* Communicate around a ring
- Afternoon
  - Review of programming exercise
  - MPI – non-blocking communication
  - Laplace equation II: Implementation with MPI
  - Thinking Parallel II: Performance considerations

Parallel Programming with MPI and OpenMP

Wednesday

- Morning – Introduction to OpenMP
  - Thinking Parallel (III)
  - OpenMP (I)
  - *Exercises* - OpenMP
- Afternoon – More OpenMP
  - Laplace equation with OpenMP
  - *Exercises* - OpenMP (II)
  - Parallel programming bugs

Parallel Programming with MPI and OpenMP

Thursday

- Morning
  - MPI – Communicators & buffering
  - MPI – Derived data types
  - MPI – Virtual topologies
  - *Exercise*: Topologies
- Afternoon
  - Review of programming exercise
  - Hybrid programming (MPI + OpenMP)
  - Parallel I/O with MPI
  - MPI – One-sided communication
  - *Exercise*: Hybrid ‘Hello world’ programs

Location Information

References

References

- W. Gropp, E. Lusk, A. Skjellum
  Using MPI – Portable Parallel Programming with the Message-Passing Interface
  MIT Press, 2014 (Third Edition)

- W. Gropp , T. Hoefler, R. Thakur, E. Lusk
  Using Advanced MPI – Modern Features of the Message-Passing Interface
  MIT Press, 2014

- R. Chandra, L. Dagum, D. Maydan, D. Kohr, J. McDonald, R. Menon
  Parallel Programming in OpenMP

- G. Hager, G. Wellein
  Introduction to High Performance Computing for Scientists and Engineers