PRACE
AUTUMN
SCHOOL
2016

PRACE Autumn School 2016

Modern HPC Development for Scientists and Engineers

September 27-30, 2016
Hagenberg, Austria

JOHANNES KEPLER UNIVERSITY LINZ

RISC Software GmbH

IT4Innovations national supercomputing center

Welcome!

Dear participant,

the Research Institute for Symbolic Computation (RISC) of the Johannes Kepler University Linz and the IT4Innovations National Supercomputing Center of the VSB-Technical University of Ostrava are happy to welcome you at the PRACE Autumn School 2016! PRACE ("Partnership for Advanced Computing in Europe", www.prace-project.eu) is a European non-profit association with 25 member countries; its mission is to enable high impact scientific discovery and engineering research and development across all disciplines to enhance European competitiveness for the benefit of society. PRACE also seeks to strengthen the European users of HPC in academy and industry through various initiatives; one of them is the regular organization of "PRACE Seasonal Schools" all over Europe. We are proud that after the Spring School 2014 also the Autumn School 2016 takes place in the Castle of Hagenberg, Austria, under the general theme "Modern HPC Development for Scientists and Engineers".

This medieval castle is located in Hagenberg, a small village 20km outside of Linz, the capital of Upper Austria; it was renovated in 1989 and since then houses the RISC Institute (www.risc.jku.at); in 2013 an extension building was opened nearby the castle pond. On initiative of RISC and its industrial spinoff, the RISC Software GmbH, the Softwarepark Hagenberg (www.softwarepark.at) was established, an industrial park with more than 1000 employees working in software development and related subjects. Furthermore, the Upper Austrian University of Applied Sciences (FH Oberösterreich) has established its School of Informatics, Communications and Media (www.fh-ooe.at/en/) in Hagenberg. By the FH and various departments of the Johannes Kepler University located in Hagenberg, more than 1500 students are now educated in this village on subjects related to information technology and media. Furthermore, the Software Competence Center Hagenberg (www.scch.at) has been established as one of the largest independent Austrian research centers in the area of software. Despite of all these exciting developments, Hagenberg still has preserved its charme as a small rural village which provides a high quality for living and working. We hope that you will experience some of this flavor while you enjoy the scientific program of the school.

On the first day of the program, you will hear a keynote presentation, several reports, and a discussion on recent trends in High Performance Computing. On the other three days, you will take part in three of the six tracks on "Parallel Programming", "Intel Xeon Phi Programming", "Parallel IO", "PETSc Tutorial", "Tools for Performance Analysis", and "Advanced Parallel Programming" with tutorial presentations and hands-on programming sessions. Further keynote talks will complement your experience. On the evening of the third day, we will have a ship ride on the Danube and enjoy dinner with a nice view on the landscape of the Upper Austrian Danube valley.

We hope that you find this program attractive and interesting and that your participation in the PRACE Autumn School 2016 will have a lasting effect on your future carreer.

Wolfgang Schreiner, Michael Krieger, Thomas Ponweiser, Ondrej Jakl, David Horak, Karoly Bosa, Dieter Kranzlmüller (local organization, programme, respectively admission committee)

September 2016

I. Accommodation and Transport

Accommodation

Sommerhaus Hotel Linz
Julius-Raab-Straße 10
4040 Linz

Tel: + 43 732 2457-490 (reception, 24 hours)
Tel: + 43 732 2457-376 (office)
Fax: + 43 732 2457-39

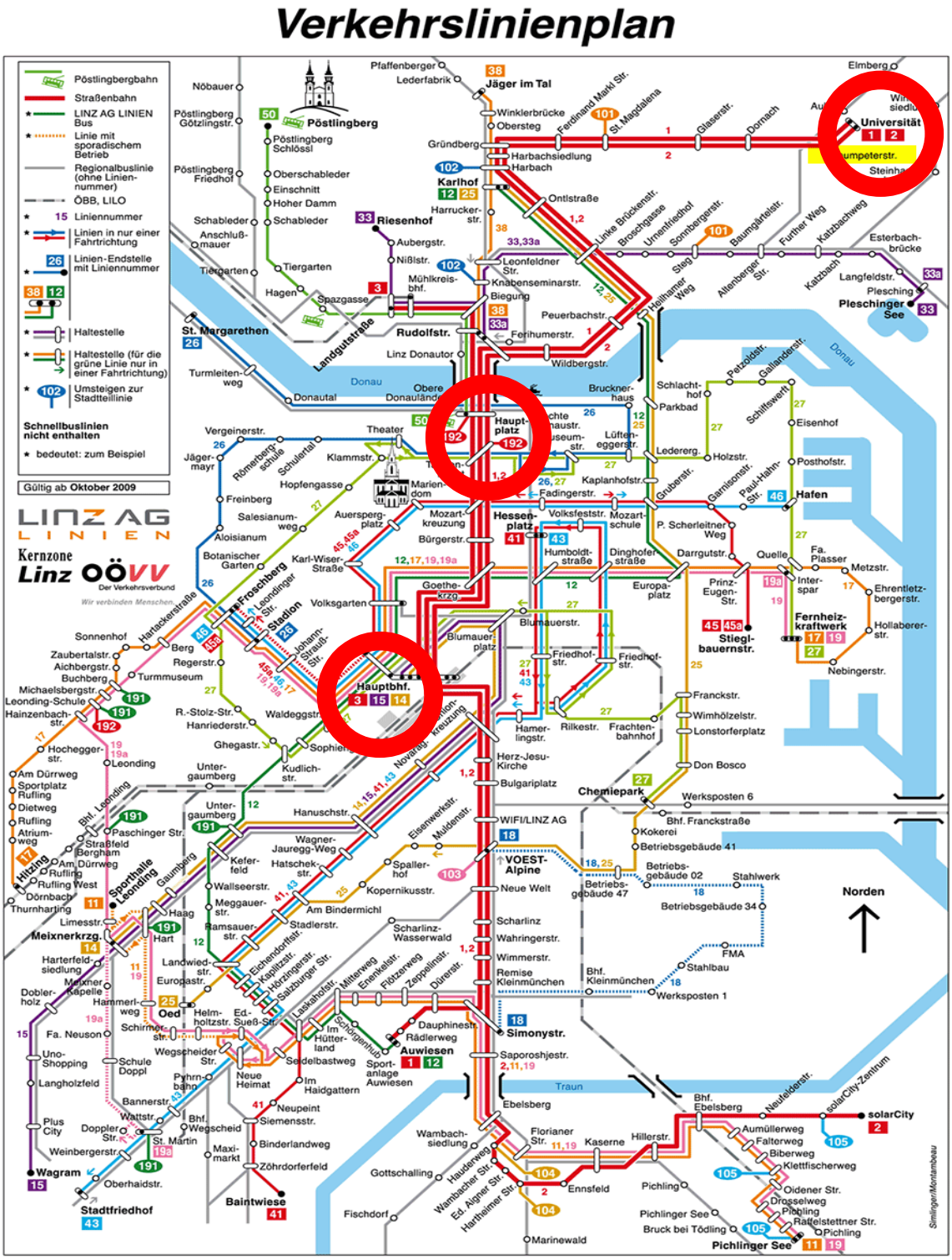
Mail: hotel@studentenwerk.at

Web: http://www.sommerhaus-hotel.at/en/linz

During the training school, the shuttle to the training school location in Hagenberg leaves every day at 8:15 from the parking lot in front of the Sommerhaus Hotel Linz (you can use it, even if you are not accommodated in the Sommerhaus, just be there on time).

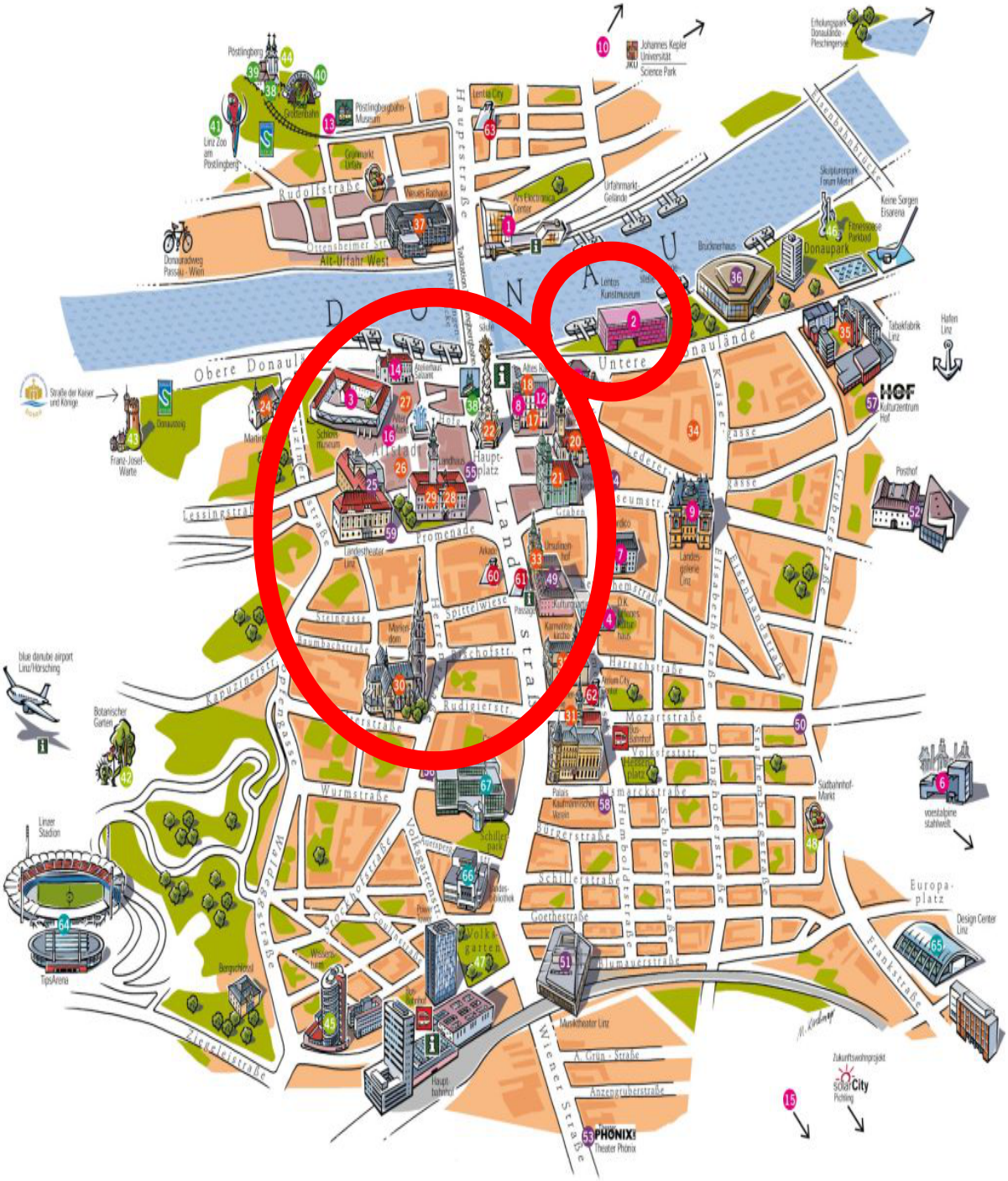
Public Transport in Linz

Take the tramway line number 1 or 2 to the station "Universität" to get to the Sommerhaus Hotel Linz. Along this line, there are also the main railroad station (station "Hauptbhf.") and the "Hauptplatz", where you can find dinner. From the Hauptplatz, you can walk 5min in the eastern direction along the Danube to the pier "Wurm+Köck" (close to the art museum "Lentos") from where we will depart for the ship ride on Thursday.



Dinner in Linz

If you want to enjoy dinner in Linz, go with the tramway to the central square ("Hauptplatz") south of the Danube (when you cross the Danube, you may notice to the east the "Lentos Kunstmuseum" ; from the pier "Wurm+Köck" close to this museum we will depart for the ship ride on Thursday. To the west of the Hauptplatz there is the old part of the city ("Altstadt"). Here and along to main road "Landstraße" to the south you will find many restaurants and bars.

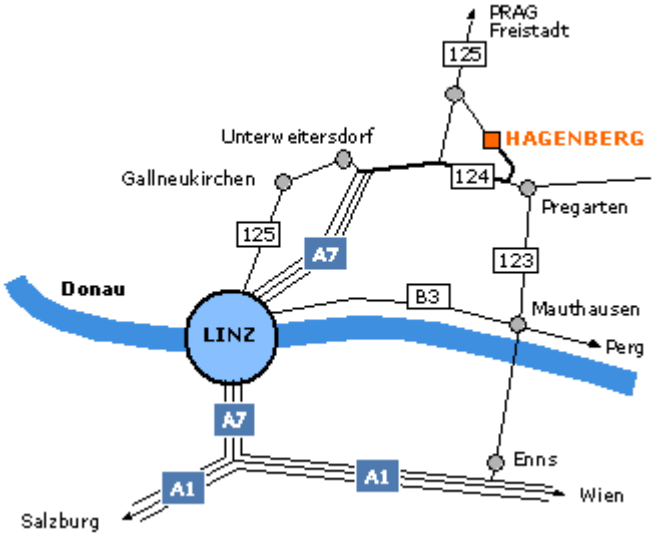


Training School Location

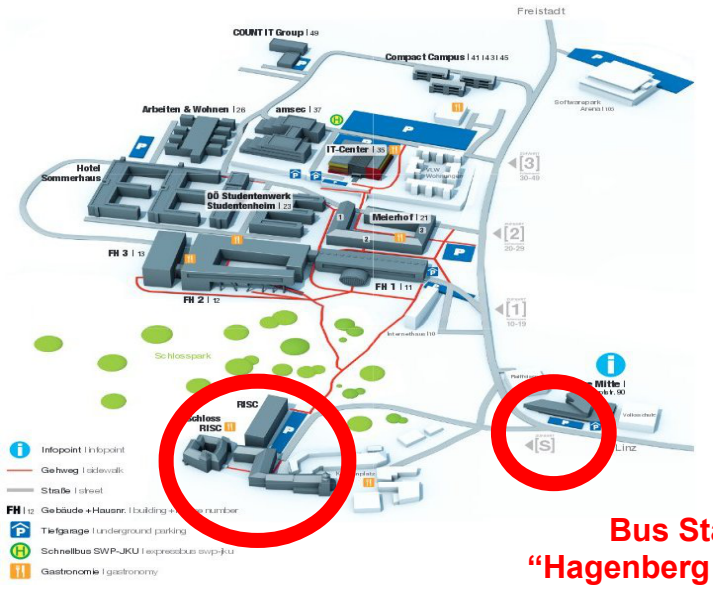
Schloss Hagenberg, Kirchenplatz 5b, 4232 Hagenberg im Mühlkreis, Austria.

The shuttle bus will bring you at 8:15 from the Sommerhaus Hotel Linz to the training school location and back in the evening. See the directions on http://www.risc.jku.at/about/map/, if you want to get to the training school location on your own.

To Hagenberg



In Hagenberg



Bus Station "Hagenberg Ortsmitte"

PRACE Training School

Castle and Pond Building Hagenberg

The training school takes place in the seminar rooms in the castle and in the extension building at the nearby pond.


Schlossrestaurant Hagenberg

Lunches take place in the Schlossrestaurant next to the castle.


II. Programme

List of Presenters

(in alphabetical order)

Dr. techn. Christoph ANTHES
Leibniz Supercomputing Centre (LRZ)

DI Dr. Christoph GONIVA
DCS Computing GmbH

Bernhard GRUBER, BSc.
RISC Software GmbH

Vaclav HAPLA, M.Eng.
VŠB-Technical University of Ostrava

Michael HAVA, MSc.
RISC Software GmbH

Dr. David HORAK
VŠB-Technical University of Ostrava

DI (FH) Alexander LEUTGEB
RISC Software GmbH

Prof. Bernhard MANHARTSGRUBER
Johannes Kepler University Linz

DI Andreas MAYR
Johannes Kepler University Linz

Dr. Sandra MENDEZ
Leibniz Supercomputing Centre (LRZ)

DI Thomas PONWEISER
RISC Software GmbH

Prof. Ulrich RÜDE
Lehrstuhl für Simulation, Friedrich-Alexander Universität Erlangen-Nürnberg

Ing. Radim SOJKA
VŠB-Technical University of Ostrava

DI Thomas UNTERTHINER
Johannes Kepler University Linz

Dr. Volker WEINBERG
Leibniz Supercomputing Centre (LRZ)

Tuesday, September 27

8:15 Sommerhaus Hotel Linz

Bus Transfer to Hagenberg

9:00-9:30 Hagenberg Castle Entry Hall

Registration

9:30-10:00 Hagenberg Castle Seminar Room

Opening: Wolfgang SCHREINER and Ondrej JAKL

10:00-11:00 Hagenberg Castle Seminar Room

Keynote: Prof. Ulrich RÜDE, Friedrich-Alexander Universität Erlangen-Nürnberg
Lattice Boltzmann Methods on the Way to Exascale

11:00-11:15 Hagenberg Castle 1st Floor

Coffee Break

11:15-12:15 Hagenberg Castle Seminar Room

Volker WEINBERG, Leibniz Supercomputing Centre (LRZ)
High Performance Computing @ LRZ

Andreas MAYR/Thomas UNTERTHINER, Johannes Kepler University Linz
Toxicity Prediction using Deep Learning.

12:15-13:30 Schlossrestaurant Hagenberg

Lunch

13:30-14:45 Hagenberg Castle 1st Floor

Poster Presentations and Coffee, Training School Photograph

14:45-15:45 Hagenberg Castle Seminar Room

Christoph GONIVA, DCS Computing GmbH
Open-Source DEM and CFD-DEM Simulations in an HPC Environment

Bernhard MANHARTSGRUBER, Johannes Kepler University Linz
Direct Numerical Simulation of a Compressible Channel Flow: Automatic Code Generation Using Computer Algebra and Parallel Implementation in OpenMP

15:45-16:00 Hagenberg Castle 1st Floor

Coffee Break

16:00-17:00 Hagenberg Castle Seminar Room

Panel Discussion: *Recent Trends in HPC*

17:15 Hagenberg Castle

Bus Transfer to Sommerhaus Hotel Linz

Wednesday, September 28

8:15 Sommerhaus Hotel Linz

Bus Transfer to Hagenberg

9:00-10:00 Hagenberg Pond Building Seminar Room

Keynote: David HORAK, VŠB-Technical University of Ostrava
Will we Live to a Zeta Machine? Development and Implementation of Scalable and Energy Efficient Algorithms

10:00-10:15 Hagenberg Castle Ground Floor

Coffee Break

10:15-11:45 Castle Seminar Room (Module 2a) and Pond Building Seminar Room (Module 2b)

Module 2a: *Parallel Programming*

Michael HAVA, Bernhard GRUBER, and Thomas PONWEISER (RISC Software GmbH)

Module 2b: *Intel Xeon Phi Programming*

Volker WEINBERG (Leibniz Supercomputing Centre LRZ)

11:45-12:00 Hagenberg Castle Ground Floor

Coffee Break

12:00-13:00 Castle Seminar Room (Module 2a) and Pond Building Seminar Room (Module 2b)

13:00-14:15 Schlossrestaurant Hagenberg

Lunch

14:15-15:45 Castle Seminar Room (Module 2a) and Pond Building Seminar Room (Module 2b)

15:45-16:00 Hagenberg Castle Ground Floor

Coffee Break

16:00-17:30 Castle Seminar Room (Module 2a) and Pond Building Seminar Room (Module 2b)

17:45 Hagenberg Castle

Bus Transfer to Sommerhaus Hotel Linz

Thursday, September 29

8:15 Sommerhaus Hotel Linz

Bus Transfer to Hagenberg

9:00-10:00 Hagenberg Pond Building Seminar Room

Keynote: Christoph ANTHES, Leibniz Supercomputing Centre (LRZ)
Virtual Reality and Visualisation in the Context of HPC Applications

10:00-10:15 Hagenberg Castle Ground Floor

Coffee Break

10:15-11:45 Castle Seminar Room (Module 3a) and Pond Building Seminar Room (Module 3b)

Module 3a: *Parallel-IO*

Sandra MENDEZ (Leibniz Supercomputing Centre LRZ)

Module 3b: PETSc Tutorial

Vaclav HAPLA and David HORAK and Radim SOJKA (VŠB-Technical University of Ostrava)

11:45-12:00 Hagenberg Castle Ground Floor

Coffee Break

12:00-13:00 Castle Seminar Room (Module 3a) and Pond Building Seminar Room (Module 3b)

13:00-14:15 Schlossrestaurant Hagenberg

Lunch

14:15-15:45 Castle Seminar Room (Module 3a) and Pond Building Seminar Room (Module 3b)

15:45-16:00 Hagenberg Castle Ground Floor

Coffee Break

16:00-17:30 Castle Seminar Room (Module 3a) and Pond Building Seminar Room (Module 3b)

17:45 Hagenberg Castle

Bus Transfer to Social Programme in Linz

Thursday, September 29

Social Programme

17:45 Bus Transfer to Pier "Wurm+Köck" in Linz

18:30 Entry to Ship "MS Linzerin"

19:00-22:30 Ride and Dinner on "MS Linzerin"

Tour "Linz - Ottensheim - Steyregger Brücke - Linz"

22:30 Tramway to Sommerhaus Hotel Linz

Friday, September 30

8:15 Sommerhaus Hotel Linz

Bus Transfer to Hagenberg

9:00-10:30 Castle Seminar Room (Module 4b) and Pond Building Seminar Room (Module 4a)

Module 4b: *Advanced Parallel Programming*

Alexander LEUTGEB (RISC Software GmbH)

Module 4a: *Tools for Performance Analysis*

Thomas Ponweiser (RISC Software) and Sandra MENDEZ (Leibniz Supercomputing Centre LRZ)

10:30-10:45 Hagenberg Castle Ground Floor

Coffee Break

10:15-12:15 Castle Seminar Room (Module 4b) and Pond Building Seminar Room (Module 4a)

12:15-12:45 Pond Building Seminar Room

Closeup

12:45-14:00 Schlossrestaurant Hagenberg

Lunch

14:00 Hagenberg Castle

Bus Transfer to Hotel Sommerhaus Linz

Abstracts

Keynote: Lattice Boltzmann Methods on the Way to Exascale

Ulrich RÜDE, Lehrstuhl für Simulation, Friedrich-Alexander Universität Erlangen-Nürnberg

The Lattice Boltzmann method uses explicit time stepping and thus a standard space decomposition can achieve good scalability. We propose an architecture-aware co-design of the models, algorithms, and data structures that leads to excellent node performance, combined with a scalability up to a million parallel threads. We will present examples how such a parallel solver can be interfaced toother tools to enable complex coupled multi-physics simulations.

Keynote: Will we live to a Zeta Machine? Development and Implementation of Scalable and Energy Efficient Algorithms

David HORAK, VŠB-Technical University of Ostrava

IT4Innovations National Supercomputing Center (IT4I, http://www.it4i.cz) at VSB-Technical University of Ostrava is currently the only national HPC research infrastructure in the Czech Republic and as such it is presented in the National Road Map of Large Infrastructures for Research, Experimental Development and Innovation of the Czech Republic. It is a national node of PRACE pan-European e-infrastructure, conducts world-class excellent research, and significantly participates in educational activities. IT4I established MSc. and PhD. studies in Computational science. IT4I provides Czech researchers with access to all services of this e-infrastructure (ANSELM and SALOMON clusters) and opens opportunities to establish international cooperation. The centre conducts research in the areas of earth science simulations for disaster management, traffic management, numerical modelling for engineering, physics and chemistry, development of libraries for parallel computing, modelling for nanotechnologies, soft-computing methods, recognition and presentation of multimedia data and safe and reliable architectures, networks and protocols. It participates at many international projects as PRACE, EXA2CT, HARPA, ANTAREX, READEX, SESAME NET, ESA, TEP, IPCC, etc. IT4I is a member of PRACE-RI and ETP4HPC. The centre has also strong link to industrial sector, it cooperates with INTEL Corp., ŠKODA AUTO, CONTINENTAL, Howden ČKD compressors, Honeywell, Bonatrans, etc.

The team of Supercomputing for Industry and HPC libraries at IT4I is focussed on development of highly scalable algorithms for solution of linear and non-linear problems arising from different engineering applications, their massively parallel implementation and their performance end energy consumption optimization. All these algorithms are based on domain decomposition methods (DDM) preserving so called numerical scalability, i.e. number of iterations does not depend on problem size. These algorithms have been implemented into our in-house software packages PERMON, ESPRESO and BEM4I, which demonstrate high scalabilities up to tens of thousands of cores.

The presentation deals with PERMON libraries (http://permon.it4i.cz) for large scale quadratic programming (QP). PERMON forms a collection of software libraries, uniquely combining QP algorithms and DDM, built on top of the well-known PETSc framework for numerical computations. Among the main applications are contact problems of mechanics. Our PermonFLLOP package is focused on non-overlapping DDM of the FETI type, allowing efficient

and robust utilization of contemporary parallel computers for problems with billions of unknowns. Any FEM software can be used to generate mesh and assemble the stiffness matrices and load vectors per each subdomain independently. Additionally, a mapping from the local to the global numbering of degrees of freedom is needed, and non-penetration and friction information in case of contact problems. All these data are passed to PermonFLLOP, which prepares auxiliary data needed in the DDM. PermonQP, a general purpose QP solver, is then called in the backend to solve the resulting equality constrained problem with additional inequality constraints in case of contact problems. PermonQP can be used also standalone for applications where QP arise like least-squares regression, data fitting, data mining, support vector machines, control systems, and others. It can potentially wrap TAO solvers and, the other way around, extend TAO with possibility to solve problems with linear equality and/or inequality constraints.

Keynote: Virtual Reality and Visualisation in the Context of HPC Applications

Christoph ANTHES, Leibniz Supercomputing Centre (LRZ)

Visualisation is a crucial tool to understand simulation results and has a long tradition in the HPC community as information visualisation and scientific visualisation. Both areas, where information visualisation deals with data which does not have inherent spatial properties like in bioinformatics, networks and charts and scientific visualisation always comes with spatial properties like in fluid dynamics or molecular structures have been widely used by the community to increase the insight in the generated data.

Traditional methods use desktop applications, often over the network, or generate static images and pre-rendered movies. Alternative approaches especially in the area scientific visualisation make use of Virtual Reality (VR) technologies. The advantage of the technology - interactive stereoscopic 3D display - helps significantly the understanding of 3D structures.

This talk will give an overview of the different visualisation approaches in HPC. It will focus on the use of traditional VR technology as well as the current developments in the VR field and the applicability for HPC.

Presentation: High Performance Computing @ LRZ

Volker WEINBERG (Leibniz Supercomputing Centre LRZ)

With the 6.8 PFlop/s system SuperMUC the Leibniz Supercomputing Centre of the Bavarian Academy of Sciences and Humanities at Garching near Munich is operating one of the fastest supercomputers in the world. We give an overview of the HPC systems installed at LRZ, and describe services and research activities like HPC training and application enabling for current and future computer architectures.

Presentation: Direct Numerical Simulation of a Compressible Channel Flow: Automatic Code Generation using Computer Algebra and Parallel Implementation in OpenMP

Bernhard MANHARTSGRUBER, Johannes Kepler University Linz

The numerical simulation of turbulent flows is one of the most prominent applications in high performance computing. While the governing equations are known for almost 200 years, their solution is still a demanding task. For the simulation of turbulent flows in fluids engineering, the use of a grid size fine enough to resolve all geometric features of the flow down to microscale postulated by Kolmogorov in the 1941 is still not feasible in most cases due to the lack of memory and CPU time available under economical constraints. This so called direct numerical simulation, direct in the sense of resolving all flow features without the use of empricial turbulence models, is restricted to scientific applications, such as boxes of isotropical turbulence or wall bounded flows such as channel flows between parallel walls or forward and backward facing step geometries. One popular approach in direct numerical soltuion of the Navier Stokes equations is the use of high order finite differences for the spatial discretization. In the case of weakly compressible flows, the combination with explicit Runge-Kutta schemes provides a low memory scheme allowing for a high number of grid points. The choices of the spatial and temporal discretization schemes, a number of different boundary conditions to be applied to walls, inflow, and outflow regions and a number of options how the boundary conditions are implemented gives rise to a high number of possible software implementations that are difficult to handle without some automation in the code generation.

In this talk, first a computer algebra package written in Maple is presented. This package allows for automatic generation of a finite difference discretization of arbitrary order including the proper treatment of boundary situations where the computational stencils are automatically adapted near edges as well as corners of the box shaped three-dimenisonal domain. After adding a time integration scheme, a linearized stability analysis on low grid sizes can be used to check the overall convergence of the code including all boundary conditions. Then the Maple package writes a Fortran Code using OpenMP for parallelization with a simple domain decomposition along a box shaped channel of totally 1000 by 1000 by 10000 cubic cells. Parallel computation with up to 256 cores has been tested on an SGI UltraViolet 1000 system. Visualization of the turbulent flow results with comparision to existing data available from literature as well as scaling results of the parallel implementation from 8 to 256 cores will be presented in the talk.

Presentation: Open-Source DEM and CFD-DEM Simulations in an HPC Environment

Christoph GONIVA, DCS Computing GmbH

Discrete Element Method (DEM) coupled to Computational Fluid Dynamics (CFD-DEM) is a powerful tool for optimization and design of particle processes. The numerical modelling of typical industrial scale applications comes at enormous computational costs or rigorous model simplifications. Therefore it is essential to have a code framework which is (i) suitable for parallel computing and (ii) scalable on large scale HPC infrastructure. These requirements to software and hardware should not come at the cost of usability for the software developers who in in case of modelling of physical processes are mostly physicists and not computing scientists. We will present the approaches chosen to balance the needs from physical modelling perspective and computational science perspective for our open source DEM code LIGGGHTS [1] and the CFD-DEM code CFDEMcoupling [2]. Further we will show some benchmarks of this codes and discuss remaining challenges.

[1] LIGGGHTS: source code available at http://www.liggghts.com

[2] CFDEMcoupling: source code available at http://www.cfdem.com

Presentation: Toxicity Prediction using Deep Learning.

Andreas MAYR/Thomas UNTERTHINER, Johannes Kepler University Linz

Everyday we are exposed to various chemicals via food additives, cleaning and cosmetic products and medicines - and some of them might be toxic. However testing the toxicity of all existing compounds by biological experiments is neither financially nor logistically feasible. Therefore the government agencies NIH, EPA and FDA launched the Tox21 Data Challenge within the "Toxicology in the 21st Century" (Tox21) initiative. The goal of this challenge was to assess the performance of computational methods in predicting the toxicity of chemical compounds. State of the art toxicity prediction methods build upon specifically-designed chemical descriptors developed over decades. Though Deep Learning is new to the field and was never applied to toxicity prediction before, it clearly outperformed all other participating methods. We show that deep nets automatically learn features resembling well-established toxicophores. In total, our Deep Learning approach won both of the Tox21 panel-challenges (nuclear receptors and stress response) as well as the overall Tox21 Grand Challenge, and thereby sets a new standard in tox prediction.

Module 2a: Parallel Programming

Part 1: Parallel Programming with OpenMP and C++

Michael HAVA, Bernhard GRUBER (RISC Software GmbH)

Part 1 of the module focuses on parallel programming techniques using threads on shared memory architectures.

After covering the theoretical background of multithreaded programs, we introduce OpenMP as state-of-the-art API in HPC environments. The parallelization of loops and synchronized access to shared variables using reductions, locks and atomic operations is demonstrated. OpenMP scheduling strategies are also discussed. As the focus is put on basic parallelization, advanced features of OpenMP such as vectorization, tasks and offloading are skipped.

Thn we will cover alternatives to OpenMP for C++. With C++11 basic threading facilities were standardized as part of the C++ language and standard library. Furthermore, modern threading libraries such as Intel's Threading Building Blocks (TBB) are available, which usually integrate better into C++. Beside loop-based parallelization, the use of atomics and concurrent data structures is demonstrated.

Part 2: Modern MPI programming

Thomas PONWEISER (RISC Software GmbH)

Part 2 of the module focuses on basic as well as certain selected advanced topics of MPI. In particular new features such as non-blocking or sparse neighbourhood collectives, are presented. Special attention is also put on best practices for achieving good program performance, based on the presenter's experience from the support of recent PRACE Preparatory Access Type C projects.

Module 2b: Intel Xeon Phi Programming

Volker WEINBERG (Leibniz Supercomputing Centre LRZ)

In this module, Intel’s Many Integrated Core (MIC) architecture is introduced. The session covers various programming models for Intel Xeon Phi coprocessors (like native mode vs. offload mode, OpenMP and MPI parallelisation etc.) as well as some selected optimisation techniques. Hands-on sessions are planned to take place on an Intel Xeon Phi based system at VSB.

Module 3a: Parallel-IO

Sandra MENDEZ (Leibniz Supercomputing Centre LRZ)

This module covers parallel IO concepts related with parallel file systems, IO techniques and performance analysis. Furthermore, it introduces the IO libraries MPI-IO, SIONlib and high level libraries HDF5 and NetCDF. The theoretical part will be complemented by practical exercises for each presented library.

Module 3b: PETSc Tutorial

Vaclav HAPLA and David HORAK and Radim SOJKA (VŠB-Technical University of Ostrava)

The Portable Extensible Toolkit for Scientific computing (PETSc) is a modular library for linear algebra, non-linear solvers, time integrators, optimization, and spatial discretization. Solver configuration and diagnostics are valuable skills for users, whether calling PETSc directly or via one of many higher level packages that access PETSc solvers. The tutorial will start with the fundamental linear algebra components then proceed to principles of preconditioning and Krylov solvers, convergence diagnostics, performance analysis, and the higher level solver interfaces. It will contain hands-on exercises to build the skills necessary to evaluate methods and design solvers for complex problems in science and engineering.

Module 4a: Tools for Performance Analysis

Thomas Ponweiser (RISC Software) and Sandra MENDEZ (Leibniz Supercomputing Centre LRZ)

This module gives an introduction to effective strategies for analysing performance and IO behaviour of HPC applications. The focus will lie on HPCToolkit for performance analysis as well as on Darshan, Vampir and TAU for IO Profiling and IO Tracing. Hands-on sessions shall lower the threshold for attendees to actually using these tools in the course of their every-day work.

Module 4b: Advanced Parallel Programming

Alexander LEUTGEB (RISC Software GmbH)

Modern Multi-Core CPUs offer different levels of parallelism in hardware. In order to make best use of this potential a common knowledge from a programmer's point of view is essential. Besides the computation power also the available memory bandwidth has a major impact on the overall performance of an algorithm. So a deeper understanding of memory hierarchies and the problems of caching in a parallel context is beneficial for the design of parallel algorithms. In order to estimate the attainable performance (floating point operations per second) of an algorithm for the execution on a certain machine the roofline model was introduced. It correlates the attainable performance with the operational intensity of an algorithm. Thereby the roofline is defined by the peak memory bandwidth and the peak performance of a machine. Because of the data width increasement of vector units over the past decades, the utilization of data level parallelism in algorithms is crucial for reaching peak performance on modern architectures. From the programmer's point of view the utilization of data level parallelism can be obtained via different techniques, ranging from the usage of vectorized libraries to programming in inline assembler using the vector instructions directly. The auto vectorization support of C/C++ compilers offers a good compromise between ease of use and programmer's control. In cases where auto vectorization is not appropriate the programmer utilizes the vector units via more explicit techniques like Vector Intrinsics or Cilk Array Notation.

III. Further Information

Wireless LAN

- **Castle**: you may connect to the WLAN hotspot

  `risc_public_hotspot`

  without authentication.

- **Pond Building:** you may connect to the WLAN hotspot

  `eduroam`

  with the eduroam account from your home academic institution. In case, you do not have such an account, please use the temporary account that you find on a separate sheet in your conference bag.

Addresses and Contacts

Training School Location:

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