Programming Complex Heterogeneous Parallel Systems

Duration: 20 hours

Teachers:
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Abstract
With the end of Moore law for sequential computing architectures and the advents of multi and many cores era, managing parallelism is no longer the goal of a restricted community but becomes a need for everybody who is interested in exploiting an adequate fraction of available performance provided by widespread modern computing architectures, including desktop and mobile devices. A computer is nowadays a complex system with heterogeneous computational units including multi cores CPU and many cores accelerators such as GPU or others. The aim of the course is to provide a glance of the different aspects involved in efficient and effective programming of Complex Heterogeneous Parallel Systems (CHPS). Overall, the considered goals in programming these architectures will be portability and performances of software to ensure effectiveness and efficiency of target applications. We will consider the complete architectural stack from hardware to applications design putting in evidence the correlation among the different levels. In particular, we will show, with practical cases, how the design and implementation of application software can exploit available computational resources through a suitable selection of programming and communications libraries, compiling and profiling tools and options, and design and implementation strategies. At this regards the course will include a hands on part that the student may dedicate to a general case study or to a personalized case depending on specific interests.

Program

- Introduction to complex heterogeneous parallel systems (CHPS): from personal computer to High Performance clusters (1 hour)
- A coarse grain analysis of performances and programming issues for CHPS, including: memory hierarchies and data movement; computational units and different levels-types of parallelism; communications issues; load balancing (3 hours)
- The case of CPU + GPU based systems (2 hours)
- Overview of parallel programming libraries, languages and tools; this will include an overview of MPI, CUDA, OpenMP, OpenACC; main features of GNU, PGI and Intel compilers; main features of Scalasca and other performance profilers (6 hours)
- Designing parallel applications and practical experiences: hands on case studies from linear algebra, computational geometry and Monte Carlo simulation. Individual case study on topics proposed by students will be encouraged (8 hours)
- Wrap up

References

- Slides of the course will be provided to students
- David B. Kirk, Wen-mei W. Hwu, “Programming Massively Parallel Processors – A Hands-on Approach”, Second Edition, Morgan Kaufmann – Elsevier, 2013
- Rolf Rabenseifner, Georg Hager, “MPI+X - Hybrid Programming on Modern Compute Clusters with Multicore Processors and Accelerators ”, Tutorial at Supercomputing 2014 – SC14, New Orleans Nov. 2014, IEEE-ACM
- Markus Geimer, Bert Wesarg, Sameer Shende, Brian Wylie, SC'14 Tutorial “Hands-on Practical Hybrid Parallel Application Performance Engineering”, New Orleans No. 2014, IEEE-ACM
- Emannuel Jeannot, Julius Zilinskas eds. “High Performance Computing on Complex Environments”, Wiley Series on Parallel and Distributed Computing, 2014
- Emanuele Danovaro, Andrea Clematis, Antonella Galizia, Giuseppe Ripepi, Alfonso Quarati, Daniele D'Agostino, “Heterogeneous architectures for computational intensive applications: A cost-effectiveness analysis” J. Computational Applied Mathematics 270: 63-77 (2014).