Thematic CERN School of Computing 2020

Sunday, June 7, 2020 - Saturday, June 13, 2020

Split, Croatia

Academic programme

The school will focus on the theme of **Efficient Scientific Software for Heterogeneous Architectures**. The complete programme will offer 25 hours of lectures and hands-on exercises, as well as an additional student presentations session, and a special evening lecture.

Introduction lecture

Scientific and computing challenges in fundamental physics
by Ivica Puljak (University of Split)
Big question and challenges in modern science, with emphasis on fundamental physics
Connecting great theoretical ideas and modern experiments to test them
Future challenges in computing: from traditional increase in data throughput, volume and complexity to emerging concepts of quantum computing, machine learning and artificial intelligence

Track 1: Technologies and Platforms

4 hours of lectures and 4 hours of hands-on exercises
by Andrzej Nowak (TIK)

Introduction to efficient computing
The evolution of computing hardware and what it means in practice
The seven dimensions of performance
Controlling and benchmarking your computer and software
Software that scales with the hardware
Advanced performance tuning in hardware

Hardware evolution and heterogeneity
Accelerators, co-processors, heterogeneity
Memory architectures, hardware caching and NUMA
Compute devices: CPU, GPU, FPGA, ASIC etc.
The role of compilers

Data-oriented design
Hardware vectorization in detail – theory vs. practice
Software design for vectorization and smooth data flow
How can compilers and other tools help?

Summary and future technologies overview
Teaching program summary and wrap-up
Next-generation memory technologies and interconnect
Rack-sized data centres and future computing evolution

Track 2: Parallel and Optimised Scientific Software

4 hours of lectures and 4 hours of hands-on exercises
by Sebastien Ponce (CERN)

Writing parallel software
Amdahl's and Gustafson's laws
Asynchronous execution
Finding concurrency, task vs. data parallelism
Using threading in C++ and Python, comparison with multi-process
Resource protection and thread safety
Locks, thread local storage, atomic operations

Modern programming languages for HEP
Why Python and C++ ?
Recent evolutions: C++ 11/14/17
Modern features of C++ related to performance
Templating versus inheritance, pros and cons of virtual inheritance
Python 3, and switching from Python 2

Optimizing existing large codebase
Measuring performance, tools and key indicators
Improving memory handling
The nightmare of thread safety
Code modernization and low level optimizations
Data structures for efficient computation in modern C++

Practical vectorization
Measuring vectorization level
What to expect from vectorization
Preparing code for vectorization
Vectorizing techniques in C++: intrinsics, libraries, autovectorization

Track 3: Programming for Heterogeneous Architectures

4 hours of lectures and 4 hours of hands-on exercises
by Daniel Campora (Nikhef)

Scientific computing on heterogeneous architectures
Introduction to heterogeneous architectures and the performance challenge
From general to specialized: Hardware accelerators and applications
Type of workloads ideal for different accelerators
Trade-offs between multi-core and many-core architectures
Implications of heterogeneous hardware on the design and architecture of scientific software
Embarrassingly parallel scientific applications in HPC and CERN

Programming for GPUs
From SIMD to SPMD, a programming model transition
Thread and memory organization
Basic building blocks of a GPU program
Debugging and profiling a GPU application

Parallel cross-architecture programming
Data locality, coalesced memory accesses, tiled data processing
Control flow, synchronization, atomics
Other standards: SYCL, HIP, OpenCL
Middleware libraries and cross-architecture compatibility

Design patterns and best practices
GPU streams, pipelined memory transfers
Good practices: single precision, branchless, avoid register spilling, convert the problem
Reusable parallel design patterns with real-life applications
Under the hood: Warps, masked execution, floating point rounding

Additional lectures

Student presentations session

Special evening lecture
Future of the Universe and of Humanity
by Ivica Puljak (University of Split)