Summer School

High Performance Computing in Multibody System Dynamics
(Parallel-Computing, GPU-Programming)

Content of the Course:

This course discusses recent trends in the hardware industry that make this an opportune time for using modeling and simulation to attack problems that, up until recently, have been considered intractable. The focus is on mechanical systems comprised of many bodies that interact through bilateral (joint-type) and unilateral (contact-type) constraints. The equations of motion for these systems are posed as collections of Differential Variational Inequalities whose numerical solution is mapped onto hardware that supports parallel computing on a variety of platforms: GPU cards, multi-core CPUs, or clusters. The course will briefly highlight each solution stage required to find out the evolution of systems with millions of degrees of freedom. The approach proposed is implemented into an open source simulation engine called
Chrono, which has been used to characterize the mobility of ground vehicles operating on deformable terrain, the flow of granular material, and fluid-solid interaction processes.

**Short Bio of Prof. Dan Negrut:**

Dan Negrut received his Mechanical Engineering Ph.D. in 1998 from the University of Iowa under the supervision of Professor Emeritus Edward J. Haug. He spent six years working for Mechanical Dynamics, Inc., a software company in Ann Arbor, Michigan. In 2004, he served as an Adjunct Assistant Professor in the Department of Mathematics at the University of Michigan, Ann Arbor. He spent 2005 as a Visiting Scientist at Argonne National Laboratory in the Mathematics and Computer Science Division. At the end of 2005, Dan joined the Mechanical Engineering faculty at the University of Wisconsin-Madison. His interests are in Computational Science and he leads the Simulation-Based Engineering Lab (http://sbel.wisc.edu). Lab sponsors include the National Science Foundation, US Army, NVIDIA, MSC.Software, Caterpillar, Simertis GmbH, and FunctionBay. The lab’s projects focus on high performance computing, large scale multibody dynamics, terrain modeling and simulation, and numerical integration methods for dynamic systems. Dr. Negrut received a National Science Foundation Career Award in 2009. Since 2010 he has been a NVIDIA CUDA Fellow. He is the co-founder and current Director of the Wisconsin Applied Computing Center.

**Participants:**

Bachelor, Masters and PhD students who are interested in parallel computing and particle simulation.

**Location:**

Technical University Darmstadt, Institute of Structural Dynamics, Room 562, Otto-Berndt-Strasse 2, 64287 Darmstadt, Germany

**Date:**

08. July (9.00h) – 12. July (16.00h) 2019

**Further Information:**

The summer school is free of charge. Participants are requested to bring along a notebook, which is necessary for the exercises.

**Speaker:**

Professor Dan Negrut – University of Wisconsin/Madison – USA
## Schedule

### Day 1:
- Operating system considerations. Package management. Shell programming; command line operations
- Command line: grep and regular expressions. SSH, X11 Forwarding, Compression.
- Cluster job submission/scheduling via SLURM. Intro, version control systems
- Version control with git
- Version control with git; concepts related to team-development; workflows

### Day 2:
- Interpreted languages overview (Python/Matlab/R). Brief overview of C/C++: variable types and declaration; pointers; etc.
- Brief overview of C/C++: variable types and declaration; pointers; memory allocation; functions; etc.
- Brief overview of C/C++: memory and pointer issues
- Compiling and linking. Static, shared, dynamic libraries.
- Debugging & Profiling

### Day 3:
- Code documentation (doxygen). Build Management via CMake
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- Elements of computer architecture: from C code to machine instructions
- Instruction Level Parallelism
- Memory issues: Caches

### Day 4:
- Memory issue: Virtual Memory Elements of software optimization – memory aspects
- Elements of software optimization – vectorization aspects
- Finite precision arithmetic aspects
- Algorithms and Data Structures

### Day 5:
- High performance computing and high throughput computing
- Continuous integration services. Software licensing aspects