18th INTERNATIONAL CONFERENCE ON COMPUTER METHODS IN MECHANICS

18 – 21 MAY, 2009

ZIELONA GÓRA, POLAND

The CMM2009 participants are kindly invited to the 3-day course:

hp-ADAPTIVE FINITE ELEMENT METHODS

which will be taught by **Professor Leszek Demkowicz** (ICES, The University of Texas at Austin) and his collaborators.

The course will precede the CMM2009 conference on **14-16 May, 2009** and consist of lectures and labs (8 hrs per day).

Traditional, low order, finite element discretizations are well suited to resolve complex topologies and curvilinear geometries. The corresponding rates of convergence are limited by the polynomial order, and the regularity of the solution. Those include not only singularities coming from non-convex geometries and material interfaces but also regions with high gradients, (e.g. boundary layers) perceived by the computer in the preasymptotic range as singularities. In presence of problems with large geometrical or material contrasts, they "lock" (100 % error). For wave propagation problems, they suffer from large dispersion (phase) errors making solution of problems with large wave numbers impossible.

Spectral methods do not lock for singularly perturbed problems, and deliver exponential convergence, provided the solution is analytic up to boundary, i.e. no singularities are present on the boundary, They do not suffer from dispersion error for wave propagation. If the solution is, however, singular on the boundary or material interfaces, the advantage of using spectral methods is lost - the convergence slows down to algebraic rates again. They also behave very badly in the preasymptotic range if the meshes do not reflect well the structure of the solution. For complex curvilinear geometries, meshes are difficult to generate.

hp Finite Element Methods combine advantages of low order and spectral methods. The short course presents fundamental technological components of hp Finite Element Methods, including:

- Mathematical foundations (variational formulations, construction of H^1-, Hcurl-, and H(div)-conforming elements, convergence estimates).
- Construction of hierarchical shape functions.
- hp data structures.
- Constrained approximation.
- Geometry modeling. Exact geometry and isoparametric elements.
- Projection-based interpolation.

The hp technology culminates in a fully automatic hp-adaptive strategy in which element size h and polynomial degree p are automatically selected to construct a sequence of optimal meshes which deliver exponential convergence for both regular and singular solutions. The methodology is based on a coarse-fine grid paradigm where the fine grid solution guides optimal hp-refinements of the coarse grid. We shall discuss two versions of the hp-algorithm:

- The energy-driven hp-algorithm.
- The goal-driven hp-algorithm.

This 3-day course will include a hands-on presentation of 1D and 2D hp codes, and a large number of 2D and 3D numerical examples, for both elliptic and Maxwell problems, focusing on wave propagation applications. For details on the subject, see [1,2]. Materials for the course will include a copy of [1] (along with 1D and 2D hp codes) and an electronic copy of all presentations. We will help to install the 1D and 2D codes on the participants' laptops. The laptops have to operate under LINUX and must have the Intel Fortran 90 and C compilers preinstalled.

The CMM2009 participants interested in the course are requested to register at http://www.cmm.uz.zgora.pl
The course fee, including a copy of the book [1], is 270 euro.

[1] L. Demkowicz, *Computing with hp Finite Elements. I.One- and Two-Dimensional Elliptic and Maxwell Problems*, Chapman & Hall/CRC Press, Taylor and Francis, October 2006.

[2] L. Demkowicz, J. Kurtz, D. Pardo, M. Paszynski, W. Rachowicz and A. Zdunek, *Computing with hp Finite Elements. II. Frontiers: Three-Dimensional Elliptic and Maxwell Problems with Applications*, Chapman & Hall/CRC Press, Taylor and Francis, August 2007.