Spectral/hp Element Method and its application in fluid dynamics

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The talk will present the family of numerical methods, which allow highly accurate approximations of smooth solutions to PDEs and its applications in simulations of fluid dynamic problems.

We will touch advantages of the high-order methods, which are in lowering of the numerical dissipation or in a kind of direct control over the error produced in spatial coordinates. We will provide a brief explanation of these aspects and basic theoretical ideas on which we can build the highly accurate numerical solution. The global (spectral) method seems to be the most effective, but complicated geometries of computational domains enforce localisation and decomposition of the domain to the elements also in the case of rich expansion spaces. Decomposition of the computational domain into elements and the requirement of C^0 continuity among them makes the Spectral Elements coinciding with the hp Finite Elements. We will show some differences between high and low degree approximations, decay of expansion (spectral) coefficients and increase of computational demands with geometrical deformations, need of high-order approximation of curved boundaries and high order integration rules.

The high accuracy is not always achievable and this fact is not dependent on computational resources only, but we can show successfull applications of the Spectral/hp Element Method in advanced flow simulations, solution of the Navier-Stokes-Fourier system with variable material properties (viscosity, density, thermal conductivity), detail studies of flow separation in transition from laminar to turbulent flow or fluid-structure interaction studies of turbine blade flutter.