A Finite Volume Formulation of Compact Schemes with Application to Time Dependent Navier-Stokes Equations

Sergey Smirnov

The objective of this thesis is to develop a high-order compact Padé-type finite volume method that can be applied on irregular structured meshes. Padé schemes are based on the use of an implicit formula to evaluate an approximated quantity, which allows for a higher-order accuracy on only a compact stencil. These schemes have a better spectral resolution than classical finite difference and finite volume methods, which makes their use interesting in applications in which solution contains a wide range of physical scales that have to be properly resolved, such as DNS and LES of turbulence. The Padé type schemes were originally formulated in the finite difference context. Their application on uniform Cartesian meshes is relatively simple, but their extension to general meshes is not straightforward. In the recent years there appeared several papers dealing with formulation of Padé schemes on curvilinear meshes, both in the finite difference and finite volume contexts. However, they all treated the problem of curvilinearity of the grid in the computational space, i.e. by the method that requires calculation of a Jacobian transformation of coordinates, which can be an extra source of numerical inaccuracies on meshes with non-smoothly varying mesh spacing. In this thesis, a finite volume Padé scheme has been formulated in the physical space, taking into account the irregularity of the mesh in the most straightforward way. It has been applied to a variety of model problems, such as 1D and 2D convection equations on Cartesian and curvilinear grids as well as to solution of different fluid mechanics problems, including LES of a turbulent channel flow.