



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
SHORT ABSTRACT OF THESIS

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Thesis Title: Development of Kinetic-Theory-Based High-Resolution Schemes for the Euler and Navier-Stokes Equations of Gas Dynamics

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SHORT ABSTRACT

This thesis proposes new kinetic-theory-based high-resolution schemes for the Euler and Navier-Stokes equations of gas dynamics. The schemes exploit the well-known connection that the Euler and Navier-Stokes equations are suitable moments of the Boltzmann equation of kinetic theory. In order to develop a high-resolution scheme for the Euler equations the collisionless Boltzmann equation is discretized using Sweby's flux limited method and the moment of this Boltzmann level formulation gives the Euler level scheme. It is demonstrated how conventional limiters and an extremum-preserving limiter can be adapted for use in the scheme to achieve a desired effect. A one-dimensional (1D) scheme is formulated first and an extension to 2D on Cartesian meshes is carried out next through dimensional splitting. Accuracy analysis suggests that the scheme achieves between first and second order accuracy as is expected for any second order flux-limited method. The scheme is carefully validated by computing various test cases ranging from moderate to high complexity. As far as the computation of viscous flow is concerned, one common strategy followed by researchers is that the scheme for the Euler equations is still used for the inviscid fluxes whereas "central differencing" is used for the viscous fluxes. When the present flux-limited scheme is used in this fashion to solve the Navier-Stokes equations it is observed that the time-step has to be prohibitively small for obtaining accurate results. In order to overcome this problem, instead of the collisionless Boltzmann equation, collision term is approximated by Bhatnagar-Gross-Krook (BGK) collision model in the full Boltzmann equation. The Chapman-Enskog expansion of the velocity distribution function is used to split the viscous fluxes. These new split fluxes result in a modification of the expression of the conservative numerical flux of the scheme for the Euler equations to become a Navier-Stokes solver. Various viscous flows are computed to validate the scheme. In addition, to obtain better timewise efficiency a new flux-corrected methodology based kinetic scheme for the Euler equations is developed. The scheme does not require any flux splitting or calculation of error functions like that in the flux-limited kinetic scheme, and hence reduces computational cost significantly. A somewhat approximate yet effective method of implementing the schemes on triangular unstructured grids is also developed. The strategy is validated through some 2D computations of reasonable accuracy. The results presented in the thesis are checked for grid independence.