A GENERAL CODE FOR MODELING MHD FLOWS ON PARALLEL COMPUTERS: VERSATILE ADVECTION CODE

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Abstract. A general tool for solving MHD and hydrodynamical problems typical of astrophysical applications is designed and implemented. The code allows the user to solve a hyperbolic system of partial differential equations with a variety of modern high resolution numerical schemes on 1, 2 or 3D non-uniform Cartesian grids with slab or axial symmetry. The equations may contain fluxes and source terms. The boundary conditions can be chosen from a number of implemented types, – fixed, periodic, reflective or "free" – but the code is structured in a manner that allows the user to write his/her own subroutines for a new type of boundary condition, or even to implement a new set of equations. The choice of algorithms allows the user to find the optimal one for the application at hand and/or to compare results of different schemes thus gaining insight into the numerical effects. An emphasis is put on independence of computer platforms. Efficiency of the code is also a high priority, the options available for the user should not compromise the performance.

The Versatile Advection Code is under development, but it has already reached a stage when it can be used for scientific research. Since the same source code is used for 1, 2 or 3D simulations, a special purpose preprocessor translates the dimension-independent notation into standard Fortran 90. I chose Fortran 90 because it is becoming *the language* of scientific computation, it expresses parallelism clearly, and it is fully compatible with Fortran 77. At the moment, however, Fortran 90 compilers are not yet available for many computers, thus the code can be translated to Fortran 77. For parallel computers ADAPTOR, a freely distributed software by Brandes, can also produce the necessary message passing. It is also possible to translate the Fortran 90 code to CMFortran, the data-parallel language of the

Connection Machine. Simple Perl scripts and a makefile take care of the precompilation procedure.

The modular structure of the code allows for a choice of the equations to be solved, at the moment four systems of equations are available: the Euler equations of compressible hydrodynamics with adiabatic or full energy equation, and the ideal/resistive MHD equations with isothermal or full energy equation. The number of spatial dimensions and the number of components for the vector variables (e.g. velocity and magnetic field) may have 6 different combinations for each system of equations.

At present three algorithms are available for solving the differential equations. The Flux Corrected Transport (FCT) scheme by Boris and Book and its later variation by Odstrčil, a Total Variation Diminishing (TVD) scheme with a Roe-type Riemann solver, and a Lax-Friedrich type TVD scheme with no Riemann solver. Both TVD schemes can use different limiters. The TVD schemes were extensively discussed and developed by Yee. All schemes are explicit, they are able to follow shocks and other discontinuities as well as smooth flows accurately. The methods differ in their abilities to resolve contact discontinuities, to suppress unphysical oscillations, and in their robustness to handle extreme situations. For MHD calculations the divergence of the magnetic field may be forced to remain zero by a projection scheme. The user can select among the available options by setting switches in a parameter file. The initial conditions are created by a separate program, VACINI. The user is not limited by the existing options, new subroutines may be added, or the initial file can be created by other means.

The code has been extensively tested (Tóth and Odstrčil 1995) on standard numerical tests. In spite of its general design, VAC is faster than or as fast as other less general codes, the comparisons were made on a DEC Alpha work station. VAC has successfully run on DEC 5000 and Cray C90 computers compiled in Fortran 77, and on Connection Machine 5 using CMFortran. Tests on other parallel machines with message passing are planned for the near future. The algorithms will be generalized and developed further. Non-Cartesian grids and implicit methods are the two major extensions that are planned.

For more information on this project please contact the author.

Reference

G. Tóth and D. Odstrčil, *Comparison of some Flux Corrected Transport and Total Variation Diminishing Numerical Schemes for Hydrodynamic and Magnetohydrodynamic Problems* , submitted to J. Comp. Phys., 1995