Recent developments about overlapping grids for unstructured meshes

P. Brenner[1]
ASTRIUM ST – 66, route de Verneuil – 78133 Les Mureaux – France

ABSTRACT

Overlapping grid techniques are very attractive for the simulation of flows around bodies in relative motion. Nevertheless for supersonic flows where strong shocks are expected, conventional CHIMERA methods quickly become ineffective since they are based on interpolation techniques between meshes. It is the reason why we have developed intersection algorithms: one grid is embedded in the other by calculating the exact geometric intersection at the border of the embedded grid. In our method [4], some cells are fully covered and are therefore excluded from the computation, others are fully uncovered and the remaining class consists of cells that are partially covered and that are connected to the overlapping grid through the intersection surface. The use of a general unstructured finite volume solver (i.e. that can work on any kind of cells) finally allows ensuring a transparent transfer of information between meshes: that simply acts to compute the numerical fluxes on the intersection surface which becomes in fact a simple interface between several cells of a same composite grid.

So, two very important ingredients are needed for the correct working of the code: a technique for calculating efficiently a geometric intersection between several grids and an unstructured solver which is robust and accurate on all kinds of meshes. Very recently, we improved these two components of our software:

- We have generalized the calculation of intersection with an arbitrary number of nested levels (a grid can be overlapped by several other grids which themselves overlap one another) whereas before, each grid could overlap only one other grid... We also optimized the algorithm to reduce CPU consumption to “the minimum”.
- We have implemented into the aerodynamic solver an algorithm to obtain an arbitrary order of accuracy. This technique relies on a compact numerical scheme (i.e. that uses only the direct neighborhood of each cell control) and works on the primitive variables which ensures a great robustness for the simulation of high enthalpy flows when upwind [2] fluxes are used.

These two major developments in the code are based on two simple ideas:

- For the generalization of intersections, it suffices to decompose a multiple intersection in a sum (or a difference) of simple intersections. Therefore, if one [1] already knows how to calculate a simple intersection, the determination of multiple intersections is only to make the algorithm recursive.
- Regarding the aerodynamic solver, it is based on the MUSCL method [3]: accuracy depends on the order of the reconstruction and thus on the estimation of the multiple derivatives of the variables to be reconstructed. To determine these derivatives, the basic idea is that a second derivative is just the derivative of a first derivative... Therefore only the direct neighbors are required but the process becomes iterative. Moreover, an original method based on the concept of the K-Exact reconstructions [5] was developed to make consistent these different derivatives for the conservative variables [6]. Finally, an adaptation of the algorithm allows the use of primitive variables without loss of precision which ensures a high robustness for high-enthalpy flow simulation. At the moment only the third order of accuracy has been implemented but the method is fully universal. Ongoing studies will enable us to determine the required order of accuracy to implement efficiently VLES models.

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[1] pierre.brenner@astrium.eads.net