Overset composite grids for the simulation of flows in complex moving geometries

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Abstract

The overset composite grid method, also known as the Chimera overset grid technique (named after the composite monster of Greek mythology), provides a very powerful means of handling complex stationary and moving geometries in computational fluid dynamics (CFD). This method has been used successfully over the last decade and a half, primarily to solve problems involving fluid flow in complex, often dynamically moving, geometries [1]. For example, transonic flow around the complete space shuttle vehicle with over 16 million grid points was simulated successfully using overset composite grids [3] and an unsteady flow around a tilt rotor helicopter under forward flight was solved with moving overset composite grids [2]

The overset composite grid method is a way of assembling multiple grids and treating them as a single grid. Basically, this method consists in generating a set of structured components grids that cover the computational domain and overlap where the components grids meet [4]. Typically, boundary-fitted curvilinear grids are used near the components boundaries while one or more background Cartesian, O-type or C-type grids are used to handle the bulk of the domain (figure 1). In this way, this method offers an effective way to reduce a geometrically complex problem into a set of simple components grids, allowing arbitrary movement of the components grids and scalability on parallel computer platforms [6].

There are three majors steps involved in the traditional overset composite grids scheme: (i) geometry and components grids generation, (ii) an algorithm for determining how to cut holes in the components grids which are overlapped, and (iii) an algorithm for interpolating field data between the various grids.

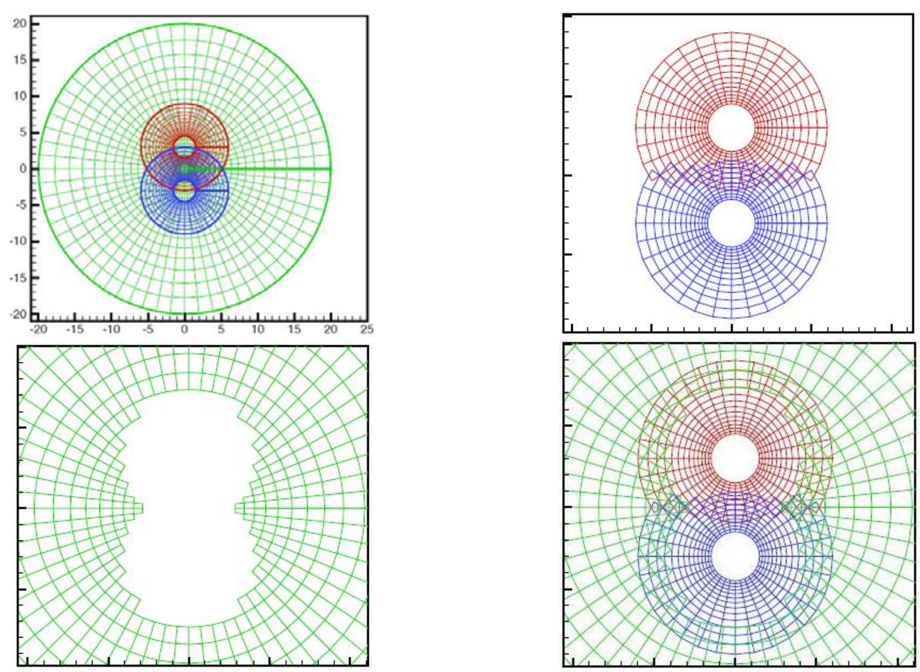

Figure 1. Steps in the overset grid algorithm, left to right, top to bottom. 1) Computational domain with components grids and main grid. 2) Components grids after cutting holes and point elimination. 3) Main grid after cutting hole and point elimination. 4) Final overset composite grid.

In step (i), a clean geometry description is created and then is exported to a grid generation software (this is mainly CAD work), then a set of structured grids is created, each one defining a particular component of the overall geometry. One of these grids must cover the entire computational domain, this is the main grid. All other grids will be components grids (figure 1). These grids are generated independently of each other. Also an alternating digital tree (ADT) is built for each grid involved in the overset composite grid methodology; this is done for fast geometric searching [1].

In step (ii), grid points are eliminated in both the main grid and the components grids. First, points in the components grids are eliminated, namely all points which are outside the computational domain and all points which overlap with other components grids and which are not needed for the solution interpolation (figure 1). Next, all points in the main grid that are overlaid by components grids and which are not needed for the interpolation are eliminated. Doing so, a chimera hole is created in the main grid (figure1).

In the final step (iii), inter-grid communication occurs by interpolating data between the components grids. Usually, trilinear interpolating functions are chosen because they are fully compatible with second order finite volume solvers [6]. In case of more than one underlying grid, interpolation is done on the finest underlying grid.

For moving bodies, step (ii) and (iii) are recursively repeated as the moving grid traverses through the computational domain, according to the dynamics and kinematics of the desired motion. The automation of this process makes the present methodology a powerful tool for the simulation of flows with one or multiple moving bodies, since the grids do not have to be regenerated as the solution evolves. Only the locations of the interpolation points used to communicate information between the grids is recomputed at each time step, an operation which can be performed very efficiently.

In the present work, two test cases using the overset composite grids methodology were treated. In the first case, a slotted airfoil is analyzed and the results are compared with the results obtained using an unstructured mesh approach. In the second case, a NACA0012 airfoil undergoing plunging and heave oscillations is analyzed and the results are compared with data from the literature [5].

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