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A Review on Overset Grid Method for Numerical Simulation

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***Abstract*: Overset grid method is an emerging, increasingly important and powerful tool in numerical simulation of fluid dynamics problems. A model built with the overset mesh technique consists of multiple spatially superimposed grids, one for each moving element and a background grid for fluid domain and stationary parts. The moving elements includes rotors in pumps, aircraft engines, internal combustion engine and naval boats. Boundary information is exchanged between these grids via interpolation of the flow variables. This technique is very useful in approximating complex fluid-structure interaction with large topology changes. Several test cases have been studied and it is found that overset grid approach is better suited for solving fluid dynamic problems with large topology changes compared to traditional methods. This paper investigates different methodologies and applications of overset grid approach in different fields of numerical simulation.**

***Keywords*: Chimera Grid, Overset Grid**

1. Introduction

.In the field of Computational Fluid Dynamics (CFD), simulating complex problems considering deforming bodies, large topology changes of multiple bodies is difficult using traditional methods like attach-detach, mesh deformation. For this Overset Grid Approach (OGA) or Chimera Grid method can used to simulate the above mentioned problems with ease [1]. Fluid dynamics numerical simulation of moving components within the fluid domain is done using overset grid approach and is seen in several papers of simulating internal combustion engines, naval simulation, and aircraft simulation, etc. overset mesh grid provides use of structured mesh for different moving components with good mesh quality. Traditional method of mesh regeneration is extremely time consuming and error prone. Advantages of overset grid approach are simulating complex geometry, moving geometry and Cartesian grids can be used for better accuracy of simulations. Disadvantages of overset grid approach are increased computational power requirements. This paper aims to brief about methodology and different application of overset grid approach in numerical simulation of fluid dynamic problems since the investigation and actual implementation of overset grid in simulation is limited.

2. Methodology

The basic methodology of overset gird is as follows. Overset grids are created as regular mesh grids but the fluid domain and stationary components of simulation are combined and meshed as single entity. The moving components are meshed separately. During computation, the background mesh is fixed while the small grids are able to move freely or as prescribed without deformation or regeneration. This effectively circumvents the large and often excessive error-prone dynamic deformation of a single-block mesh as well as the complex and time-consuming mesh regeneration. A.R. Koblitz (2017) investigated direct simulation with overset grids [2]. He illustrates that the method of overset grids (also called overlapping, overlaid or Chimera grids) bridges the stationary and boundary conformal grid methods. A composite grid G consists of logically rectangular component grids Gk, with k = 1, 2... Ng. As illustrated in Fig. 1 the grid points of G are classified as interior points, boundary points, interpolation points and exterior or un-used points. When moving grids are used, as is the case in particulate flow problems where each particle is represented by a separate component grid, the relative position of overset grids changes continuously. As a result, overlapping connectivity information, i.e. Chimera holes (regions of exterior points in the overset component grids) and interpolation points, must be recomputed at every time-step. Crucially, this is cheaper than complete grid regeneration and the required connectivity information re-computation can be locally confined to those grids affected by the moving grid. Values of the solution at interpolation points are determined by standard tensor-product Lagrange-interpolation. This interpolation is not locally conservative. Locally conservative interpolation on overset grids is possible. Corrections to ensure global conservation are also possible.

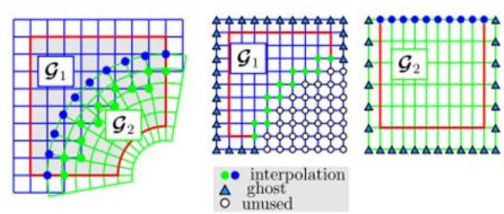

Fig. 1. Interpolation on overset grid [2].

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A.W. Vreman (2017) has proposed a staggered overset grid for simulating incompressible flow around moving spheres and illustrated that a staggered overset grid for moving spheres is constructed and simulated [3]. Fan Jingjing and Yan Chao investigated enhancement of overset grid assembly in which they Alternating Digital Tree data structure for identification of donor cells along with over optimization of overset grids [4]. Omer Faruk Sukas and et al. (2017) assessed planning hulls using overset grid in navel simulation and illustrated 2DOF simulation of hull of a boat using overset grid and validated it with the experimental results [5]. Z.H. Ma and et al. (2018) proposed an overset mesh for numerical simulation of water entry problems. It is observed that the overset hole cutting and interpolation schemes used for the test case of dam breaking is conducted and validated with experimental results captured by high speed camera [6].

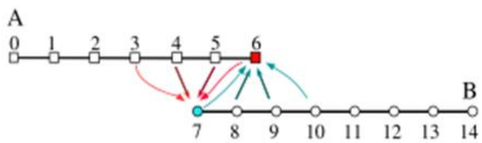

Fig. 2. Overlapping of two 1D meshes. Interpolation of fringe points [6]

Fig. 3. Hole cutting of two overlapping meshes [6].

Fig. 2 illustrates about the overlap and interpolation of field variables during simulation of overset grids. Fig. 3 illustrates hole cutting procedure for a body fitted mesh used in subdomain B to deal with structure. The grey points on domain A are the holes for which the field variables are not computed. Fig 4 elucidates the flow chart of multiphase flow solver with overset grid with domain connectivity.

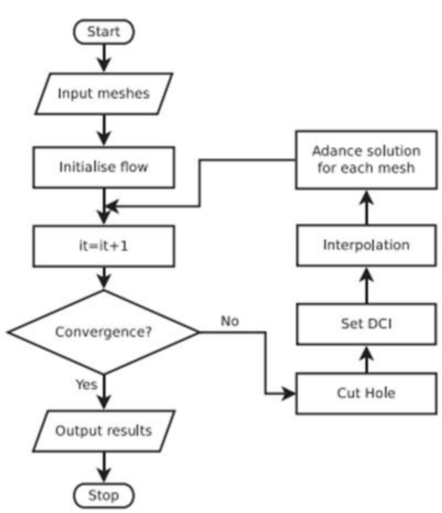

Fig. 4. Flow chart of overset grid simulation [6].

The domain is meshed and the overset mesh is spatially superimposed on to the background domain and then the flow is initialized. The holes are cut in the domain then for the boundary conditions given the field variables are solved and interpolated to the background mesh and for the next time step the same is continued until convergence is achieved. The methodologies employed for different simulation for different problems may vary but the overset grid method used in those will provide good results.

3. Applications

As mentioned before overset grid assembly is used for numerical simulation which include large topology or positional or locational changing application like naval simulation, particulate particle simulation, multiphase flow simulation, 6DoF simulations of ships, planes, etc. this section reviews different applications of overset grid. Z.H. Ma and et al. simulated a free falling life boat using overset grid. It is inferred from the work that meshing was done using an open source tools called Gmsh and sappyHexMesh provided with OpenFOAM. The convergence study was carried out by running on successively refined mesh and convergence was achieved for local pressure, force and displacement of the structures. It is concluded that the overset grid approach is far superior to the traditional methods for dynamic problems. Fig. 5 are the post processed results of the overset grid simulation of the free falling hull and Fig. 6 and Fig. 7 are the plots of field variables of the wedge such as pressure, acceleration, velocity and force on the body. From the plots we can conclude that the simulation result from successive refinement goes very well with the experimental results [6]. Jianhua Wang and et al. has performed a numerical simulation of ships in waves using overset grid method using Open FOAM. Overset grid method and 6DoF module is used to solve the motions of the free running ship with twin rotating propellers and turning rudders of ONR Tumblehome model 5613 boat. Here multiple overset grids are spatially superimposed on a single domain. The multiple overset grid includes rotors, rudders and the whole boat. The standard 10/10 zigzag manoeuvre with actual rotating propellers and rudders in various wave environment has been simulated and concluded than the overset grid method can be effectively used to handle problems for naval simulation with different wave conditions [7].

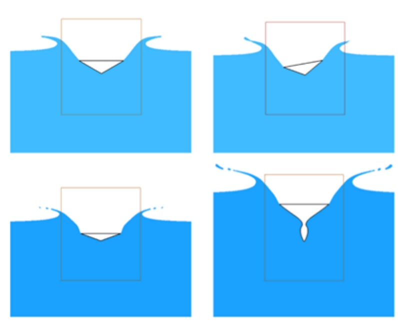
Fig. 5. Simulation of free falling hull [6]

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Andrea Berton and et al. (2017) has simulated the TCC-III optical internal combustion engine. The was built using overset grid, multiple overset for each moving elements like valves and piston and background domain for stationary elements like cylinder, ports and manifolds. From the work it can be concluded that overset method can be used to simulate dynamic problems in both Reynolds Average Navier Stokes (RANS) and Large Eddy Simulation (LES). Mass conservation error induced during simulation of overset mesh can be reduced to 0.2% of total mass of the domain [8]. A.R. Koblitz and et al. (2017) has conducted a direct numerical simulation of particulate flows using overset grid method. Flow of finite sized particles using Lagrangian-Eulerian method along with overset gird. Overset grid method shows promising result with agreement to experimental results [2].

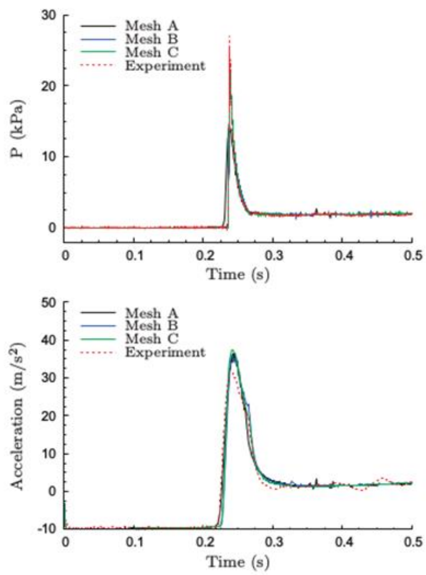

Fig. 6. Temporal Plots of Pressure and acceleration for free falling wedge [6].

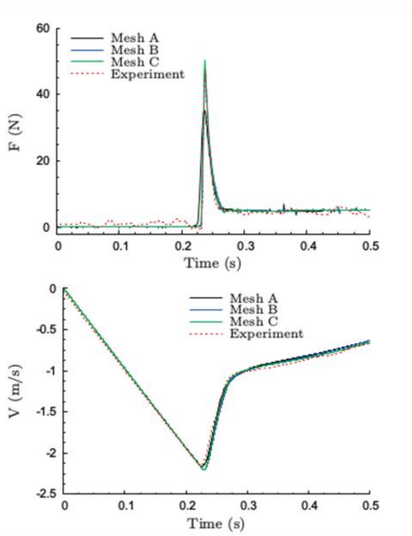

Fig. 7. Temporal Plots of Force and velocity for free falling wedge [6]

Yuwei Li and et al. (2012) has conducted a numerical simulation of wind turbine using dynamic overset grid. Simulation are carried out for different wind velocity for constant blade pitch angle for NREL phase VI wind turbine. Extensive comparison with experimental data with RANS and Detached Eddy Simulation (DES) turbulence model numerical simulation [9]. Fig. 9 depicts the assembly of overset grids of different components of a wind turbine. Each component is meshed separately like the blades, tower, nacelle and the background and are assembled. Fig. 10 illustrates about the simulation of air flow around wind turbine at different wind speeds.

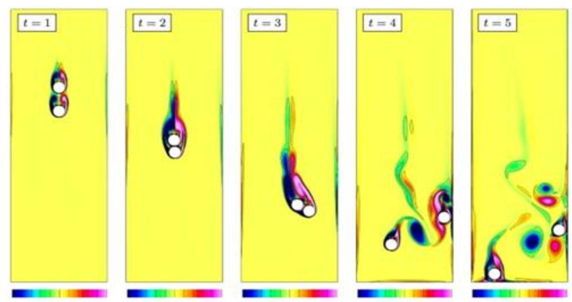

Fig. 8. Vorticity contours in different time step. Scale (-3.6, 3.6) [2]

4. Conclusion

Methodologies and different applications of overset grid methodology for numerical simulation of dynamic problems in fluid simulation has presented. Overset grid technique has proved to be acceptable and far more capable than traditional meshing methods like attach/detach, mesh morphing and mesh regeneration.

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