ON IMMERSED METHOD WITH ANISOTROPIC MESH ADAPTATION FOR PARALLEL MULTIPHASE FLOW DYNAMICS

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Summary. CFD is still strongly depending on the construction of meshes. Moreover, the flow equations are containing different scales filtered by the local mesh size, adding difficulties to tailor accurately the mesh a priori. For complex flow situation as liquid gas or fluid structure interaction involving discontinuity in the primal variables the sensitivity to the mesh can become a bottleneck. Mesh adaptation is a way of to simplify both the initial mesh construction, as the a posteriori dependency of solution to the mesh. In order to simplify CFD simulation, in particular for multiphase flows, we present here a general approach that combines immersed method and anisotropic mesh adaptation with an error estimate original technique in view to embed completely the mesh construction into the solution calculated with a stabilized optimally Finite element solver.

1 INTRODUCTION

A wider use of numerical simulation is still depending on meshing and adaptive meshing capabilities when complex geometry, multi-domain, moving interface and multiphase flow are involved. This task becomes more and more difficult when it is combined with a posteriori adaptive meshing or/and dealing with moving interfaces and boundary layers and also when running on massively parallel computers. In order to overcome the lack of flexibility of the common body fitted method, the alternative proposed here, is based on an implicit representation of the interfaces by a local distance function using a hyperbolic tangent filter. Therefore, the geometries can be interpolated and contribute to the numerical error which is detected by an a posteriori error estimator technique. This approach favours the full usage of parallel and even massively anisotropic adaptive meshing approaches providing an optimal capture of the interfaces within the volume mesh, whatever is the complexity of the involved geometries. From the flow solver side, unstructured meshes with highly distorted elements (however solution aligned) need to rely on a robust solution framework. The interface condition transfer is enforced by following the immersed boundary/volume (IVM) methodologies for fluid/fluid and or fluid/structure interaction. The proposed multiphase flow solver, including a related local level set technique is based on a stabilized finite element method (VMS with residual based stabilisation) that can afford with anisotropic meshing with high aspect ratio elements. For transient flow a complete stabilization approach including the interface stabilization term and the dynamic of the subscales will be proposed with a quasi-optimal calculation of the stabilization parameter. The error estimation and the metric calculation will be presented and various application examples will be proposed..

2 METRIC STABILITY APPROXIMATION ERROR AND IMMERSED METHOD

The presentation will follow the following issues:

A metric field, denoted by M, is introduced following the technique first given in [5]. A unit continuous metric field can be associated with a certain class of meshes, in a continuous mesh framework. Moreover, we will show that the metric provides a very simple recovery operator and it enables on one hand, to retrieve the classical interpolation error and to elaborate an approximation error on the other hand. We focus on the numerical calculation of the incompressible Navier-Stokes equation by using a mixed velocity pressure formulation with equal order finite element, mainly P1/P1 at this stage because of the current unstructured anisotropic meshing technology, well established for straight simplex elements and being under development for curved tetrahedra. The stabilisation theory gives rise to a unique framework to fulfil the infsup condition and to control the convective term. In brief, we introduce the Petrov-Galerkin formulation in which the stabilisation parameter providing the stability condition will depend on h, a mesh size field. In fact, and it is part of the novelty of this presentation, by using a duality argument (looking at the adjoint problem) h can be defined as the square root of the trace of the metric, trace(M)-1/2 , which is clearly dominated by the smallest height of elements and consequently opening clearly the door to anisotropic meshing. Indeed, the added artificial diffusion is controlled by the smallest width of the element and consequently at the least possible level.

This leads to a convergence between the residual based stabilisation method and the approximation error estimate.

The basic idea of immersed method is to represent the interfaces between domains or phases by an implicit function, here the zero value of a level set function. The parameter jumps are averaged by a smooth Heaviside function depending on thickness parameter [2]. The classical way to choose the thickness is to account for a certain number of elements. We change this point of view by fixing a priori the thickness and expecting that the mesh adaptation will give the right number of elements we need to achieve the best possible accuracy. Here again, it requires a well suited metric construction that must combine the solver error and the interpolation of the geometry, exactly evaluated by the a posteriori error estimate of the interpolated or calculated distance fields

3 APPLICATIONS

In order to show the calculation possibility of this approach, several examples will be presented in order to explain the methodology and results obtained for challenging applications. We will focus on a target industrial process in which the spatial scales and time scales can be considered as extreme for the actual state of the art. The process is the coating of an iron strip by a liquid (molten zinc) with impacted by a very high speed air jet. It combines high Reynolds effect with high capillary effect with air liquid interaction and liquid solid interaction with jump in rheology parameters at more than one to thousands. Moreover, the target layer of the liquid film is about ten micron meters related to the meter which is the scale of the entire process and effectively, the meshes can vary from one to the micron meter in certain direction.

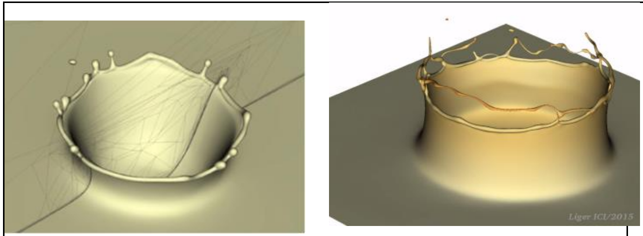
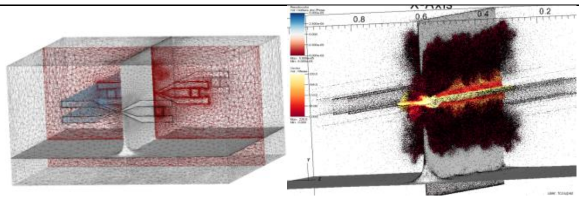
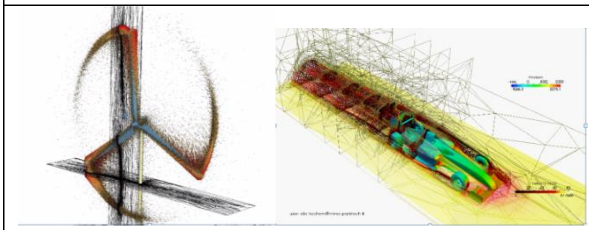
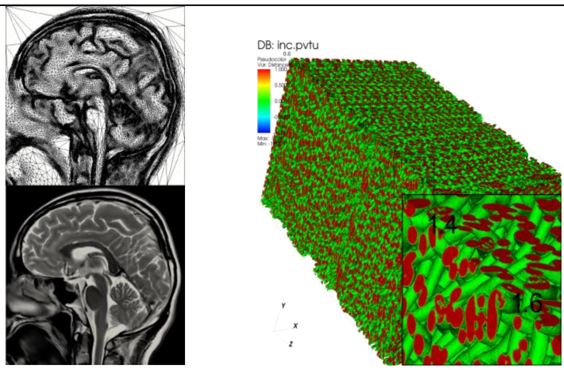
	
Milk crown flow, micro fluidic and capillary effects	Wipping process; coating in steel industry, extreme direct CFD simulation
	
flow past solid geometries (wind mills, complicated car geometry)	Mesh and calculation from 3D images (scan or tomography) medical application [4], material application [3]

Figure 1. Various applications using a monolithic approach for fluid-fluid or fluid-solid with a single adapted mesh and the implicit representation of interfaces. Dynamic anisotropic parallel mesh adaptation

3 CONCLUSIONS

Immersed method can be combined with anisotropic mesh adaptation providing a unique mesh on which a monolithic formulation can be written for various multiphase applications. In that case, the geometries involved can be integrated in the error estimate for Navier stokes by using an extension of our earlier work on the metric construction.

The inherent thickness of the interfaces of immersed methods can be well controlled a priori and the mesh adaption process delivers the optimal mesh size in the vicinity of the interfaces. Clearly, this artificial thickness gives rise to certain regularity to the solution that aims to ensure a mesh convergence. 3D complex applications show the potential of this framework.

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