8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

Transient mesh adaptivity applied to domains undergoing large deformations

*** G. Compère[13], J-F. Remacle[1], K. Hillewaert[2]**

[1] Institute of Mechanical, Materials and Civil Engineering (iMMC)
Université catholique de Louvain (UCL)
Avenue Georges Lemaitre 4, 1348 Louvain-la-Neuve, Belgium
gaetan.compere@uclouvain.be
jean-francois.remacle@uclouvain.be

[2] Centre of Excellence in aeronautical research (CENAERO)
Rue des Frères Wright, 29, 6041 Gosselies, Belgium
koen.hillewaert@cenaero.be

[3] National Fund for Scientific Research (FNRS)
Rue d'Egmont 5, 1000 Brussels, Belgium

Key Words: *3D mesh adaptivity, local mesh modifications, large deformations*

ABSTRACT

It is only recently that unstructured adaptive methods have been applied to transient problems. Transient adaptive simulations require to modify the mesh in time, especially if the domain itself is undergoing large deformations.

For that purpose, two approaches are possible. The first one requires to build a new mesh any time the mesh has to be adapted. In those global remeshing techniques, the issues related to mesh to mesh interpolation are critical.

The other way of doing the adaptation in time is to locally modify the mesh [1, 2, 4]. A common belief is that doing local mesh modifications has to be faster than remeshing. This is usually not the case. Global remeshing procedures are in fact usually faster than local mesh modifications techniques. This is essentially because global remeshing algorithms converge much faster: they allow to create vertices that are readily at their right locations when local mesh modification procedures iteratively add and remove vertices in the mesh. However, for transient adaptive computations, local mesh modifications have determinant advantages that are not linked with their computational efficiency:

- local solution projection procedures can be easily set up that ensure the exact conservation of conservative quantities [3, 4],
- the mesh remains unchanged in most of the domain, allowing to adapt the mesh frequently,

- local mesh modifications can be performed in parallel, enabling transient adaptive simulation to run on parallel computers.

The mesh adaptation procedure make use of a mesh metric field that represents the desired size of the mesh. A mesh metric field is a smooth tensor valued field $\mathcal{M}(x, y, z)$ defined over the domain that is symmetric and positive definite. Let us consider a mesh edge e that defines a vector $\mathbf{e}$ that goes from its initial vertex to its final one. The non-dimensional length L_e of e is computed as

$$L_e = \int_e \sqrt{\mathbf{e}^t \, \mathcal{M}(x, y) \, \mathbf{e}} \; dl. \tag{1}$$

The aim of the mesh adaptation procedure is to modify an existing mesh to make it a unit mesh, i.e. a mesh for which every edge is close to the size $L_e = 1$. The use of a tensor valued metric field allows the construction of anisotropic meshes.

We present an algorithm in which local mesh modification operators like edge splittings, edge or face swappings, edge collapses and node relocations are applied until every edge of the domain has a dimensionless size in the interval $L_e \in [1/\sqrt{2}, \sqrt{2}]$. This interval prevents the algorithm to oscillate between coarsening and refinement operations.

Local mesh modification operators all consist in replacing a cavity of elements $\mathcal{C}$ by another one $\mathcal{C}'$. In our adaptation procedure, we have set up a moment when both cavities $\mathcal{C}$ and $\mathcal{C}'$ are simultaneously present. At this point, the different solvers are called back so that a local solution projection procedure can be performed. The solution in the new cavity $\mathcal{C}'$ is computed using the information in $\mathcal{C}$.

Here, we extend the approach of [1] to Arbitrary Lagrangian Eulerian (ALE) computations for which the mesh encounters very large deformations. In most of ALE approaches, only vertex repositioning is considered as local mesh modifications. We show that it is possible to extend the mesh motion dramatically by using a larger set of local mesh modifications. The proposed technique is implemented in the context of a 3D finite volume Navier Stokes solver.

References

[1] G. Compère, E. Marchandise, and J-F. Remacle. Transient adaptivity applied to free surface flows. *Journal of Computational Physics*. available online.

[2] X. Li. *Mesh Modification Procedures for General 3-D Non-manifold Domains*. PhD thesis, Rensselear Polytechnic Institute, 2003.

[3] J-F. Remacle, X. Li, M. Shephard, and J. Flaherty. Anisotropic adaptive simulation of transient flows using Discontinuous Galerkin methods. *International Journal for Numerical Methods in Engineering*, 62:899–923, 2004.

[4] J-F. Remacle, S. Soares Frazao, X. Li, and M. Shephard. Adaptive discontinuous galerkin method for the shallow water equations. *International Journal for Numerical Methods in Fluids*, 52:903–923, 2006.