Goal-Oriented Mesh Adaptation for a Moving Aircraft Generating Vortex Shedding

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The scope of this paper is to create a simulation of a moving aircraft generating a vortex shedding using a moving mesh adaptation. Two mesh adaptation methods are presented for this simulation : the hessian-based mesh adaptation and the goal-oriented mesh adaptation.

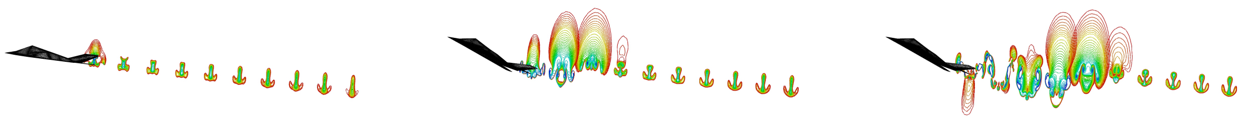

Figure 1.

Keywords : hessian-based mesh adaptation, goal-oriented mesh adaptation, ALE.

I. Introduction

When dealing with CFD problems, mesh adaptation is interesting for its ability to approach the asymptotic convergence and to obtain an accurate prediction for complex flows more easily. Anisotropic mesh adaptation methods reduce the number of degrees of freedom thus impact favorably the CPU time and reduce the numerical scheme dissipation by automatically taking into account the anisotropy of the physical phenomena inside the mesh. Anisotropic features are mainly deduced from an interpolation error estimate. The advantage of the goal-oriented mesh adaptation method over the hessian-like approach is the consideration of both the solution and the PDE in the error estimation. In this paper we will consider both of the mesh-adaptation methods to represent the vortex shedding created by a moving aircraft.

II. Mesh Adaptations for a Moving Aircraft

A. Hessian-based Mesh Adaptation

Anisotopic mesh adaptation is an iterative process. Starting from an initial couple mesh/solution $(\mathcal{H}_0, \mathcal{S}_0^0)$, the general idea is to converge both the solution and the mesh to a final state.

Given $(\mathcal{H}_i, \mathcal{S}_i^i)$, a metric tensor is computed a each vertex of the mesh $\mathcal{H}_i$. It contains information on sizes and directions of the elements of the final mesh we seek. This information given by the metric tensor field $\mathcal{H}_i$ is then used by the remesher to generate a new mesh $\mathcal{H}_{i+1}$. Then $\mathcal{S}_i$ is interpolated on $\mathcal{H}_{i+1}$: we obtain $\mathcal{S}_{i+1}$ which is then used as a restart solution for the next iteration of the mesh adaptation loop. We usually perform around 10 iterations with a growing complexity of the mesh.

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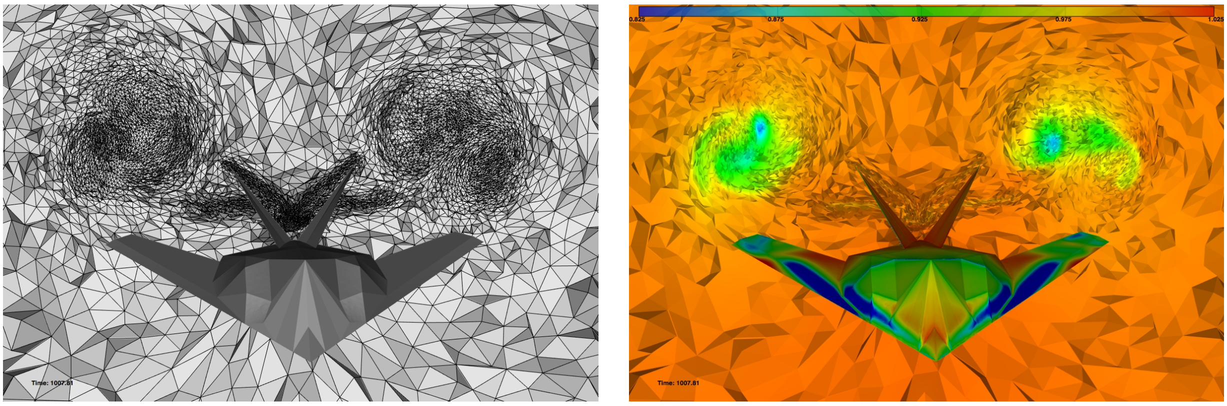

Figure 2.

B. Goal-Oriented Mesh Adaptation

The advantage of the goal-oriented mesh adaptation method over the hessian-like approach is the consideration of both the solution and the PDE in the error estimation. The adaptation criterion used is tuned to a particular functional of interest. In this case we will presented the drag or the lift. The algorithm is a global iterative process presented in Algorithm 1.

Algorithm 1 Goal-oriented Mesh Adaptation

`For j=1,nptfx`
`For i=1,nadap`
$\mathcal{S}^j_{0,i} = \texttt{ConservativeSolutionTransfer}(\mathcal{H}^j_{i-1}, \mathcal{S}^j_{i-1}, \mathcal{H}^j_i)$
$\mathcal{S}^j_i = \texttt{SolveState}(\mathcal{S}^j_{0,i}, \mathcal{H}^j_i)$
`End for`
`For i=nadap,1`
$(\mathcal{S}^*)^j_i = \texttt{AdjointStateTransfer}(\mathcal{H}^j_{i+1}, (\mathcal{S}^*_0)^j_{i+1}, \mathcal{H}^j_i)$
$\{\mathcal{S}^j_i(k), (\mathcal{S}^*)^j_i(k)\} = \texttt{SolveStateAndAdjointBackward}(\mathcal{S}^j_{0,i}, (\mathcal{S}^*)^j_i, \mathcal{H}^j_i)$
$|H_{\max}|^j_i = \texttt{ComputeGoalOrientedHessianMetric}(\mathcal{H}^j_i, \{\mathcal{S}^j_i(k), (\mathcal{S}^*)^j_i(k)\})$
`End for`
$\mathcal{C}^j = \texttt{ComputeSpaceTimeComplexity}(\{|H_{\max}|^j_i\}_{i=1,nadap})$
$\mathcal{M}^j_i = \texttt{ComputeUnsteadyLpMetrics}(\mathcal{C}^{j-1}, |H_{\max}|^{j-1}_i)$
$\mathcal{H}^{j+1}_i = \texttt{GenerateAdaptedMeshes}(\mathcal{H}^j_i, \mathcal{M}^j_i)$
`End for`

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