AN H-ADAPTIVE UNSTRUCTURED MESH REFINEMENT STRATEGY FOR UNSTEADY PROBLEMS

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***Abstract*— An h-adaptive unstructured mesh refinement strategy to solve unsteady problems by the finite element method is presented. The maximum level of refinement for the mesh is prescribed beforehand. The core operation of the strategy, namely the refinement of the elements, is described in detail. It is shown through numerical tests that one of the advantages of the chosen refinement procedure is to keep bounded the mesh quality. The type of element is not changed and no transition templates are used, therefore hanging nodes appear in the adapted mesh. The 1-irregular nodes refinement constraint is applied and the refinement process driven by this criterion is recursive. Both the strength and weakness of the adaptivity algorithm are mentioned, based on clock time measures and implementation issues. To show the proper working of the strategy, an axisymmetric, compressible non-viscous starting flow in a bell-shaped nozzle is solved over an unstructured mesh of hexahedra.**

***Keywords*— h-adaptivity, unstructured meshes, Quality metrics, hanging nodes.**

I. INTRODUCTION

The benefits of mesh adaptivity in the solution of Computational Fluid Dynamics problems by the Finite Element Method are well recognized. Amongst them, h-adaptive or mesh enrichment procedures have the advantage that they do not need to modify the fluid dynamic solver to be used.

The development of an h-adaptive element-based unstructured mesh strategy to solve unsteady problems by the finite element method is described in this work. It can be applied both to two- and three-dimensional unstructured linear finite element meshes. The adaptivity algorithm is designed considering the element refinement stage as the core of the strategy. This allows to extend the algorithm from 2-D meshes to 3-D ones with little extra effort. The refinement algorithm has been successfully tested by Rios Rodriguez *et al.* (2005), solving steady fluid dynamic problems on meshes made up of triangles, quadrangles and tetrahedra. Special care has been taken to keep bounded the quality decrease of the mesh. Edge midpoints or regular 1:4 and 1:8 refinement seems to be the best choice in this sense, for two- and three-dimensional elements correspondingly. It is also shown based on numerical tests that the best choice (from the quality standpoint) to regularly refine a tetrahedron in 8 sub-tetrahedra is to choose the shortest diagonal of the inner octaedron that arises in the partitioning process. Hanging nodes have to be managed since no transition elements are used to match zones of different refinement levels. To ensure a smooth transition in element size between zones with different levels of refinement, the 1-irregular node constraint amongst neighboring elements is considered. Consequently, the refinement process is recursively designed and the solution must be constrained on these hanging nodes. The selection method of the elements to be refined is shortly described as well. In this work, the strategy is used to solve the unsteady starting flow in a bell-shaped rocket nozzle over an unstructured mesh of hexahedra. While the adaptivity software runs on a single processor, the fluid dynamic problem solver developed by Storti *et al.* (1997-1999) runs in parallel on a Beowulf cluster. To show the algorithm efficiency, clock time is measured using a uniformly refined mesh equivalent to the adapted one. Finally, the advantages as well as the disadvantages of the strategy are highlighted.

II. ELEMENT REFINEMENT

It is considered that the main issue in the design of the refinement algorithm is to minimize the quality drop of the adapted mesh, since high quality meshes are often desired for numerical reasons. Computational cost and programming simplicity are also taken into account in the process design. If a regular 1:8 tetrahedron refinement is applied, four similar subtetrahedra are obtained at the corners of the parent element and an inner octahedron results. By adding an edge, the octahedron can be splitted into four tetrahedra, as Fig. 1 shows.

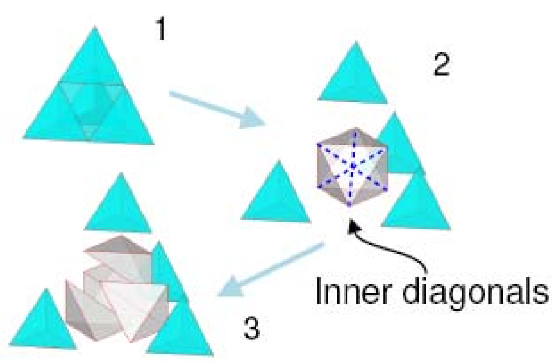

Figure 1: Regular 1:8 tetrahedron refinement sequence.

One of the three possible diagonals must be chosen (these diagonals are marked as dashed lines in Fig. 1).