Analysis of the efficiency and relevance of the Berger-Rigoutsos and the Livne cluster creation algorithms for patch-based AMR in the case of thin flagged areas

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When using the Adaptive Mesh Refinement (AMR) technique to model thermal-hydraulic phenomenons, one wants to refine the mesh on a defined set of elementary cells. Patch-based AMR aims at providing good CPU load balance during the resolution of numerical schemes. For multi-phase flows, we typically flag the location of the interface between phases and cluster the flagged points into several patches in order to be able to treat them separately. In most use cases, a computational solver will benefit from correctly distributing calculation with one processor per patch.
The Berger-Rigoutsos [1] and the Livne [2] algorithms are methods to create those said clusters. In particular, the Livne algorithm is designed to be an improvement of the Berger-Rigoutsos algorithm, which becomes only a particular case of the more general Livne algorithm. Therefore it is interesting to compare the two (effectiveness, cost, efficiency), especially in our case of interest characterized by thin flagged areas representing shock fronts or bubble-water interfaces for instance.

In this work we define three different quality functions that quantify the relevance of a patch-creation algorithm, each checking whether we reach sensible goals:

- minimize the (unnecessary) computation: this is quantified with an average efficiency η,
- minimize surface differences between patches, in order to keep a good balance between CPUs in case of multiprocessing: we will use a normalized standard deviation σ,
- minimize the communication location between patches, that is to say the segment that is common between patches. For a given area, the rectangle with the smallest perimeter is the square, so we will try to have the ratio between the length of sides as close to 1 as possible. It may not be an exhaustive criteria for communication segment length, but it appears to be a sufficient one. We will thus use an average length ratio γ.

These three quality functions η, σ and γ are dimensionless numbers, are comprised between 0 and 1 and follow the rule "the larger the better".

We will apply those quality functions to the study an initial test case: a spherical bubble which interface is clustered the same way with both algorithms, and thus give the same values for η, σ and γ. Afterwards we will study the values of η, σ and γ when the bubble is deformed into an ellipsoid by flattening it continuously. This way we will be able to analyze how efficient the two algorithms are and how they compare one to another in the scenario of a typical bubble transformation.

Références

[1] Marsha J. BERGER and Isidore RIGOUTSOS, *An Algorithm for Point Clustering and Grid Generation*, IEEE Transactions Systems, Man and Cybernetics, 21(5): 1278-1286, Sep/Oct 1991.

[2] Oren E. LIVNE, *Minimum and Maximum Patch Size Clustering on a Single Refinement Level*, University of Utah, UUSCI-2006-002, Jan 2006.

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