Topology-aware parallel unstructured mesh adaptation framework for scientific application at exascale

Pavanakumar Mohanamuraly[1 [0000−0001−9788−8664]] and Gabriel Staffelbach[1 [0000−0002−0843−743X]]

CERFACS, Toulouse, France mpkumar@cerfacs.fr

1 Abstract

Exascale machines present new set of challenges to scientific computing. In particular, building topology-awareness has become critical to maximise machine utilisation and minimise energy cost associated with data movement. In this work we present TreeAdapt a novel topology-aware online parallel mesh adaptation framework built on top of our in-house topology-aware parallel unstructured mesh partitioning and load-balancing tool TreePart [2]. The adaptation framework uses an iterative algorithm which can leverage any serial adaptation tool (supporting canonical finite element types) to realise a massively parallel mesh adaptation taking responsibility for the load-balancing and global mesh data maintenance. We use a combination of partitioning weights and cycling between a coordinate based partitioner and graph partitioner between iterations to ensures a completely different partition interface to ensure fast convergence of the desired metric. Currenlty the MMG [1] serial mesh adaptation library coupled with TreeAdapt is used in this work to demonstrate large scale parallel mesh adaptation of the sub-scale rocket combustor BKD[3] from DLR with 42 coaxial injectors fed with liquid oxygen and gaseous hydrogen. TreeAdapt tool (the command line version of treeadapt) was able to perform the mesh adaptation on 4096 MPI ranks on Epyc 2 AMD processors achieving a speedup of 5000x over existing meshing practices.

In figure 1 we plot the deviation (number of elements above 60% threshold from the target edge size) and the time take (adaptation + load-balancing) for each iteration of the parallel adaptation. As expected the geometric partitioner (RIB) outperforms (2-3x faster) the GRAPH partitioner in partitioning cost. Moreover in 6-8 iterations we achieve asymptotic convergence in the deviation. A detailed breakdown of the cost of the various components of the parallel adaptation process is shown in fig. 2.

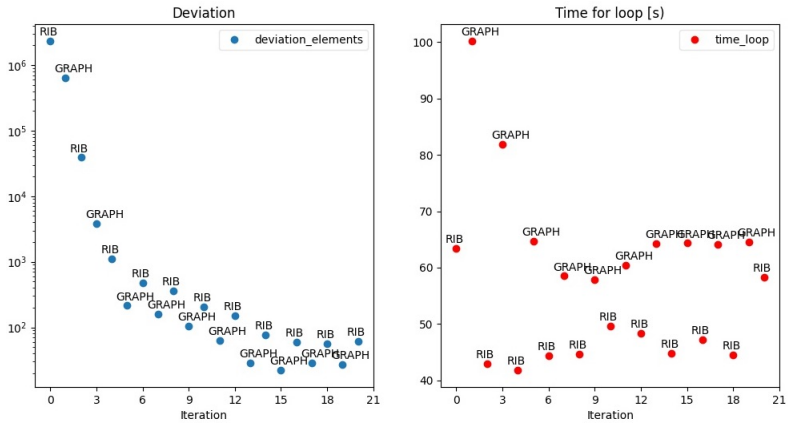

Fig. 1: Alternate cycling of RIB and GRAPH based load-balancers for the parallel mesh adaptation of the BKD test case on 4096 MPI ranks; (left) Number of elements above threshold vs iteration and (right) total time taken for adaptation + load-balancing for indicated method

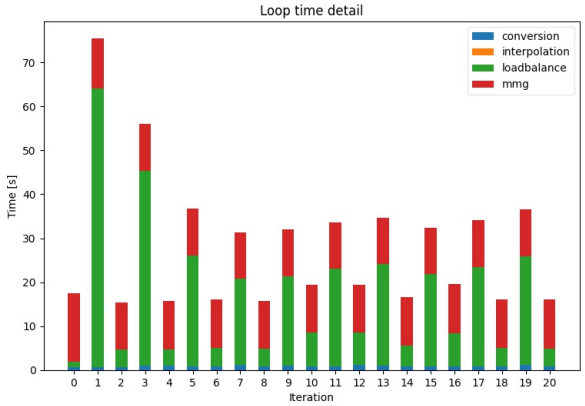

Fig. 2: Breakdown of timing information of TreeAdapt for each major step of the algorithm

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