High order anisotropic mesh adaptation basic framework

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ABSTRACT

Anisotropic mesh adaptation techniques have been shown to be very efficient in the last decade with very convincing results and even completely new domains of applications [1]. In modern anisotropic Finite Element, the element stretching can attain very high level as 1 for 1000 to 10000 when capturing boundary layers. The gain in terms of mesh points versus a uniform mesh is thus about 1000 to 10000 and it has been proven to be the only successful known solution for specific applications. These techniques are well understood and fully developed for P1 simplex element. Until now, the gain in terms of mesh entities was enough to compensate a low order numerical solution. Today, supercomputers of thousands of cores are available and enable to run computations on meshes of several millions of points including parallel mesh adaptation [4], and it changes our former point of view, since the extra cost for high order meshing could be compensated by a higher convergence order.
Beyond P1 element, the interpolation error analysis gives rise to element metrics that are not anymore constant and therefore unit meshes are not made of straight elements.
Two ways can be followed in the meshing community to go P2 elements. The first one is to mesh with classical P1 (straight) simplex elements and thereafter transform them in P2 (generally for curved boundary recovery layer.) The second way we want to explore here is a direct metric driven construction of P2 element.
For that purpose we propose to revisit the framework proposed in [1,2] for mesh generation, that combine simple algebraic topology operations and basic differential geometric considerations, with the extension and generalization of the tensor approach and associated edge based error first introduced in [3]. The novelty of this framework is to give a clue for a straightforward construction of unit meshes that provide automatically curved edges as a consequence of the minimal path definition in non-Euclidian geometry, while the conformity remains guaranty by a minimal volume principle. First examples of P2 anisotropic meshes will be shown and potential impact in applications will be discussed.

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