Efficient high-order discrete geometric model from CAD

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In the area of geometric modeling, major challenges are linked to the efficient visualization of CAD surfaces and to the generation of meshes well suited for numerical simulations. In this context, the elaboration and implementation of a discrete geometric model provide a simple and universal representation model, without the need for CAD. Such a model is a geometrically accurate representation of the model by means of a triangulation composed of polynomial elements. A first study aiming to build a discrete universal model has been carried for a model using degree 1 (one) elements, a "triangulation" composed of quadrilaterals and triangles. The advantage of this model of degree 1 lies in its geometric simplicity. However, in the case of complex surfaces, it may require a very large number of elements, in particular to represent some essential model characteristics such as high geometric curvatures. The discrete model is essentially used for visualization purpose and can also be considered for meshing. In this latter context, this discrete model is a universal representation regardless of the original analytical model which enables geometric queries (position, first and second derivatives, …) to be formulated without reference to the CAD model. In addition, another benefit of the discrete model is to isolate meshing operations from curve and surface parameterization.

This paper presents an extension of the degree 1 approach allowing to efficiently reconstruct a high order discrete geometric model (using quadric, cubic, …, elements). The reconstruction is made up of several steps. It first proceeds by discretizing and approximating patch boundary curves using polynomials of a user-specified order. Next, for each parametric domain, a grid conforming to this discretization is built. This grid is geometrically adapted through refinement in order to obtain an accurate geometric model. The resulting discrete network of curve and surface elements is then dynamically refined so that it conforms to the original CAD data within a user-specified tolerance, while minimizing the overall model size. By construction, the model is essentially composed of quadrilateral curved elements, possibly with some triangular elements in the vicinity of the boundary. Edges of quadrilaterals are aligned with parametric directions of the original surfaces and are geometrically conformal. Several numerical operations required by this reconstruction process are computationally intensive. These operations have been carefully designed to minimize computational and memory resources. Some illustrative examples will demonstrate the efficiency of the proposed approach.