SUBDIVISION FINITE ELEMENTS FOR GEOMETRICALLY COMPLEX THIN AND THICK SHELLS

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Abstract

The thesis deals with non-smooth and non-manifold subdivision finite elements for general shells and corresponding applications. In the presented approach subdivision surfaces are used for geometric modelling as well as mechanical analysis of shells. The key motivation for performing finite element analysis of the "exact geometry" provided by subdivision models is the promise of side-stepping the error prone and often user guided generation of finite element meshes. The use of the same shape functions also enables rapid data exchange between design and analysis models, which is, for instance, crucial to design optimisation.

The subdivision approach is powerful technique for generating smooth surfaces on arbitrary connectivity meshes. An important feature of the subdivision shape functions is that each shape function reaches beyond the element boundaries with which it is associated. As a result, the enforcement of boundary conditions and the treatment of non-manifold shell geometries are more difficult that the conventional Lagrangian or Hermit-type finite element shape functions. This thesis systematically develops methods for subdivision shells with non-smooth and non-manifold geometries. The introduced methods generalise the original subdivision shells and enable their application to industrial strength geometries. The developed techniques include a new strategy to extract shape functions from highly irregular mesh topologies, control of surface normal at the domain boundaries and corresponding data structures in object oriented C++. As a result, it is possible to exactly discretise shell geometries with intersections and non-smooth features.

The developed non-smooth subdivision shells are applied to thin-shell fracture and fragmentation. The original approach of embedding cracks in a shell discretised with subdivision shape functions relied on the introduction of cracks between all element edges

with the attendant duplication of mesh entities and high memory usage. The new strategy adaptively introduces cracks along the physical crack path and hence considerably reduces the number of the degrees of freedom.