NURBS solid modelling using an operator-based approach

Peter Stein
Graduiertenkolleg 1462, Bauhaus-Universitaet Weimar, Germany

Keywords: NURBS, solid modelling, operator-based modelling, BIM, isogeometric analysis

The isogeometric analysis is a rather new variant of the finite element method (FEM). The key concept of this method is to directly employ a geometric model described by parametric functions as a mesh for the FEM. The models for the isogeometric analysis have been usually based on non-uniform rational B-Splines (NURBS). The applications so far include both two- and three-dimensional models. This approach, however, leads to new problems: the creation and modification of NURBS surfaces is a common task in the field of computer graphics, but not the modelling of NURBS solids. This article describes a novel approach to modelling and storage of NURBS-based solid bodies. It is based on considering the modelling process as a sequence of operators applied to a simple initial body. These operators include affine transformations of the control points that define the solid body as well as knot insertion and degree raise. All of the aforementioned operations are common practice within the field of computer graphics. In combination, they allow a very efficient and compact representation of solid bodies.

The motivation for this work is the integration of structural analysis with building information modelling. Recent research that derived volumetric FEM meshes from building models has shown the general feasibility of this endeavour. However, it has not achieved a full coupling of the digital building models with the FEM models. That is, the numerical models have to be rebuilt for every model revision - which occurs quite often during the planning process. This has been caused by the huge amounts of data that are necessary for describing a mesh. Hence, setting up dependencies between the geometry of a building and the elements of the numerical model would be prohibitively expensive. With the isogeometric analysis based on NURBS solids a more compact formulation is available that allows a volumetric formulation of the problem. This is due to their internal representation: NURBS solids are basically a mapping from a three-dimensional parametric space into 3-space. The components of this mapping are a set of control points and their assigned basis functions. The basis functions can be uniquely determined by three knot vectors and a set of weighting factors. We have rather strict requirements on the control points, though: these have to be aligned – in a topological sense - in a regular grid. This fact hinders a compact representation of the NURBS solid. Such a possibility becomes available by representing the modelling process of NURBS solids in terms of operators. Modifications of NURBS solids can be formulated as single operations that either modify the basis functions of the solid or that transform its control points. This allows a compact and efficient storage of the solid objects. Furthermore, it strongly resembles the way that designers sculpt free-form surfaces. A prototype has been set up that includes these operations. It has shown the general feasibility of this approach.
Acknowledgements

The author would like to express his gratitude towards the German Research Foundation DFG that is supporting his research through the Graduiertenkolleg 1462.

References


ROMBERG, R., 2005, Gebäudemodell-basierte Strukturanalyse im Bauwesen, PhD thesis, Technische Universität München
