Abstract

Visual Analysis of Second and Third Tensor Fields in Structural Mechanics

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This work presents four new methods for the analysis and visualization of tensor fields. The focus is on tensor fields which arise in the context of structural mechanics simulations.

The first method deals with the design of components made of short fiber reinforced polymers using injection molding. The stability of such components depends on the fiber orientations, which are affected by the production process. For this reason, the stresses under load as well as the fiber orientations are analyzed. The stresses and fiber orientations are each given as tensor fields. For the analysis four features are defined. The features indicate if the component will resist the load or not, and if the respective behavior depends on the fiber orientation or not. For an in depth analysis a glyph was developed, which shows the admissible fiber orientations as well as the given fiber orientation. With these visualizations the engineer can rate a given fiber orientation and gets hints for improving the fiber orientation.

The second method depicts gradients of stress tensors using glyphs. A thorough understanding of the stress gradient is desirable, since there is some evidence that not only the stress but also its gradient influences the stability of a material. Gradients of stress tensors are third order tensors, the visualization is therefore a great challenge and there is very little research on this subject so far.

The objective of the third method is to analyse the complete invariant part of the tensor field. Scalar invariants play an important role in many applications, but proper selection of such invariants is often difficult. For the analysis of the complete invariant part the notion of "extremal point" is introduced. An extremal point is characterized by the fact that there is a scalar invariant which has a critical point at this position. Moreover it will be shown that the extrema of several common invariants are contained in the set of critical points.

The fourth method presented in this work uses the Heat Kernel Signature (HKS) for the visualization of tensor fields. The HKS is computed from the heat kernel and was originally developed for surfaces. It characterizes the metric of the surface under weak assumptions. i.e. the shape of the surfaces is determined up to isometric deformations. The fact that every positive definite tensor field can be considered as the metric of a Riemannian manifold allows to apply the HKS on tensor fields.