Literature Review -3

1.Boundary Element Octahedral Fields in Volumes. [Primary]
2. Tensor Field Design in Volumes. [Secondary]

Authors : JUSTIN SOLOMON, AMIR VAXMAN, DAVID BOMMES [primary]
Authors : **JONATHAN PALACIOS, LAWRENCE ROY, and PRASHANT KUMAR,CHEN-YUAN HSU,WEIKAI CHEN,CHONGYANG MA,LI-YI WEI,EUGENE**

Submitted By
Ganesh Ramani

ABSTRACT

In the primary paper, they discuss the computation of smooth fields of orthogonal directions within a volume is a critical step in hexahedral mesh generation, used to guide placement of edges and singularities. While this problem shares high-level structure with surface-based frame field problems, critical aspects are lost when extending to volumes, while new structure from the flat Euclidean metric emerges. This article presents an algorithm for computing such "octahedral" fields. The formulation achieves infinite resolution in the interior of the volume through the boundary element method, continuously assigning frames to points in the interior from only a triangle mesh discretization of the boundary.

The Secondary Paper deals with 3D tensor field design is important in several graphics applications such as procedural noise, solid texturing, and geometry synthesis. Different fields can lead to different visual effects. The topology of a tensor field, such as degenerate tensors, can cause artifacts in these applications. Existing 2D tensor field design systems cannot be used to handle the topology of a 3D tensor field. In this paper, they present the first 3D tensor field design system. At the core of their system is the ability to edit the topology of tensor fields. They demonstrate the power of their design system with applications in solid texturing and geometry synthesis.

INTRODUCTION

The design of direction fields in volumetric domains is a new problem that has gained momentum in recent years. Propelled by hexahedral mesh generation, most attention has been given to the computation of fields that assign three orthonormal directions to each point in a volume. These fields are designed to be agnostic to the ordering and sign of the individual directions at each point. Hex meshes are desirable for applications in finite element simulation. A hex mesh is essentially a warped three-dimensional grid covering a volumetric domain. The quality of a hex mesh depends on several parameters: the topological quality, reflected by a simple singularity graph; regularity, measured by evenly-sized and orthonormal hex elements; and alignment to the boundary of the domain.Therefore, the design of smooth, orthonormal, boundary-aligned fields is a critical step in hex re-meshing, and one that is pursued in this article. For the octahedral problem, volumes are flat and inherit the trivial Euclidean parallel transport, and tet mesh discretization is in a sense unnecessary for this problem. Simply put, tets do not convey meaningful geometric information for volumetric octahedral field design; they are simply a default numerical discretization of the problem. They offer a novel method to compute a smooth octahedral field aligned to prescribed boundary constraints on a triangle mesh. Their algorithm, which uses the boundary element method, uses variables sampled only at the boundary triangles. That is, we write our entire octahedral field pipeline in terms of a triangle mesh bounding the interior; the resulting field can then be queried at arbitrary points inside. Even with a coarse boundary, we obtain smooth fields, whose singularity graphs exhibit desirable structure.

In the secondary paper, we present to our knowledge the first interactive, 3D tensor field design system. The user can create a tensor field by specifying desired tensor values and local patterns inside the volume, or on the boundary surface, or in both places. The field can be made boundary-conforming, i.e., the surface normal direction is aligned with one of the eigenvectors of the tensor field everywhere on the surface.At the core of the system is a set of topological editing operations such as degenerate curve removal, degenerate curve deformation, and degenerate curve reconnection, which have been identified and used to control the number, location, and shape of degenerate curves.

METHODS EMPLOYED

The problem of representing and designing octahedral fields is relatively new. As such, discussing its basic structure.

- SPHERICAL HARMONIC REPRESENTATION :

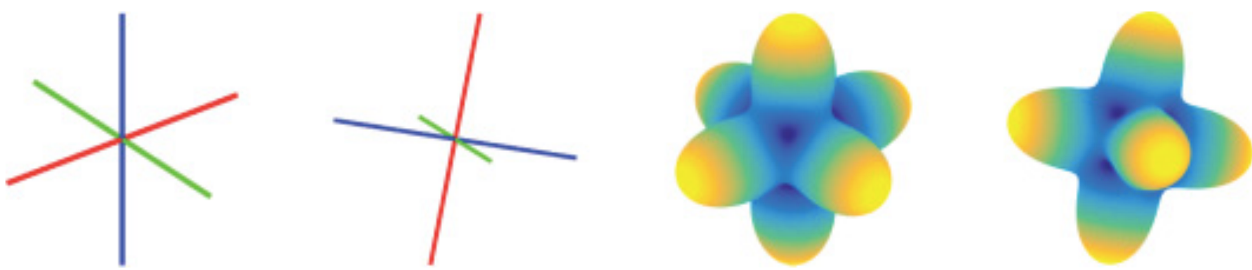
Octahedral frames are represented as rotations of a canonical function f0 (x) in the spherical harmonic basis. Other than serving as an efficient representation, this basis facilitates treatment of rotated frames by using Wigner D-matrices.

- Canonical Function :

Representing individual octahedral frames as rotations as a function on the unit sphere, where the basis of degree-four real spherical harmonic functions and $x \in S^2$. This function, henceforth referred to as the canonical axis function.

- Wigner D-Matrices :

Given a rotation R that transforms f0 into f , the corresponding degree-four Wigner-D matrix of the rotation R transforms the coefficients of f0 in the spherical harmonic basis into the coefficients of f .



- SMOOTH FIELD DESIGN :

They are optimized for octahedral frames on the boundary ∂ whose interpolation to the interior of via the boundary element method creates a smooth octahedral field. To evaluate the field at arbitrary points in the interior of they sample the field as a set of spherical harmonic coefficients and then project the interpolated coefficients.

- BOUNDARY OPTIMIZATION

The octahedral field problem involves a flat, Euclidean volumetric domain. While problems on surfaces must deal with curvature and parallel transport, these constructions are trivial.Hence, they view explicit tetrahedralization of the interior of as a means for computation.

- ALGORITHM

    - Discretization :

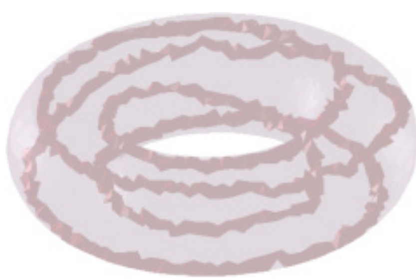
They discretize the boundary ∂ ⊆ R3 as a triangle mesh with n faces. The goal is to find one vector of u values per triangle via a piecewise constant discretization.

    - Global Step: Optimization :

The eigenvalue iteration is fast since it only requires multiplication by Q and T . Solution time is dominated by the second step; each iteration of bisection requires inversion of a dense linear system. The density is on the order of the number of boundary triangles rather than the number of tetrahedra in a volumetric mesh, however, implying a smaller size for Q than tet-based FEM.

- Interior Evaluation :

- Hexahedral Meshing



Our octahedral frames have a practical impact on hex meshing pipelines. We experiment using a variant of Nieser et al., which relies upon octahedral frames for guidance. Even without dense sampling or non-linear polishing, the singular structure and smoothly-varying frames create a symmetric hex mesh. The hexahedral meshes are robustly extracted from the parametrization with the freely available HexEx library.

3D TENSOR FIELD SPECIFICATION

1. it is important to be able to specify the tensor value at a given point in space.
2. if the desired tensor value is degenerate, it is usually important to also specify the degenerate tensor pattern near the point of interest.
3. we would like the interface to be both intuitive and easy-to-use.

- Propagation. Treat each entry in the tensor field Ti, j as a scalar field. A 3D symmetric, traceless tensor field can be considered as five scalar fields defined on the same mesh. The problem of propagating tensor values from the fixed vertices to the remaining vertices is thus converted into computing five scalar fields over the mesh. For each scalar field the values are given at the fixed vertices.

- Design. Focus is on the details of the second step, i.e., computing the set of fixed vertices and tensor values at these vertices based on user-specified design elements.

A design element can be either degenerate or non-degenerate. Together, the coefficients of Tx , Ty , and Tz form the Jacobian of the tensor field and are responsible for the local tensor degenerate patterns around the point where the constraint is placed. Given a user-specified curve, our system first generates a spline that best captures the sketched curve. The spline curve is then subsampled at a set of evenly spaced

- Parameterization. The sub samples a long a user-specified curve are usually not the vertices of the mesh.They found that such an approach leads to poor control over tensor patterns (especially degenerate patterns) near the degenerate curves.They then compute a volumetric parameterization of this neighborhood with respect to the curve, which is equivalent to deforming the neighborhood into a canonical neighborhood . Then for each vertex v inside the neighborhood, they locate the closest vertex v0 on the curve and applies the displacement vector v – v0 into v0's local linearization (to obtain the desired tensor value at v.

- Boundary-conforming tensor fields. The users often wish the designed tensor field to conform to the boundary surface of the volume, i.e., one of the eigenvector fields is aligned with the surface normal everywhere on the boundary. However, tensor fields generated from the aforementioned Laplacian system are in general not boundary-conforming. To handle this difficulty, they perform one more Laplacian smoothing using some additional fixed vertices.

- Tensor fields from curvature tensor. The user may wish the tensor field to be aligned with the curvature tensor field on the boundary surface. Once the curvature tensor has been converted into a 3D tensor field, it is included in the boundary condition.

- Local field smoothing. It is often important to reduce the topological and geometric complexity of the tensor field in a region R with the field outside R unchanged. This is achieved with the same tensor-valued Laplacian smoothing framework with different boundary conditions.

TOPOLOGICAL EDITING OPERATIONS

- Degenerate curve deformation which refers to deforming part of a degenerate curve.
- Degenerate curve reconnection which refers to cutting open two degenerate curve segments and stitching together pieces from different segments, thus resulting in two new degenerate curve segments.
- Degenerate curve removal which refers to removing either one degenerate curve or simultaneously two degenerate curves, under respective conditions .

These operations are designed to impact the least number of de- generate curves, while, together, can provide enough flexibility to modify tensor field topology

PERFORMANCE

For each test, timings are reported for separate stages of the pipeline. The global steps—construction of BEM matrices and optimization for boundary frames—are carried out on a single thread; times are reported in seconds. The local steps are easy to parallelize by sample point; since the field can be queried anywhere.

Tool has been tested on a system with Intel(R) Xeon(R) CPU with 3.40 Ghz speed with a RAM of 64 GB and an Nvidia Quadro K420 graphics card. They have tested the design system on various models, with a resolution varying from 150, 000 tets to 1, 000, 000 tets.

CONCLUSION

This work represents significant progress on several aspects of the octahedral field problem. With demonstration a pipeline in which octahedral frames can be recovered with infinite resolution even after discretization of the boundary. Our pipeline, quadratic optimization algorithm, and robust projection also overcome several challenges related to optimization in the space of frames.

In this paper they have introduced the problem of 3D tensor field design and have identified a number of graphics applications. They also provided the first 3D tensor field design system that is interactive, intuitive, and efficient. At the core of the system they provide the capability to design and control degenerate curves, which is tensor field topology.