IP1

3D Printing: Challenges and Opportunities for Geometric and Physical Modeling

3D printing (additive manufacturing) has drastically changed the design and manufacturing landscape by enabling companies to prototype and produce products faster and cheaper. However, significant challenges remain to be addressed in order to fully realize the use of 3D printing as a direct digital manufacturing approach. This talk will discuss some unique properties of 3D printing technology and related opportunities for geometric and physical modeling. Some of our recent work on new process development and design for additive manufacturing will be presented. The talk will conclude with remarks and thoughts on future 3D printing developments and new design and manufacturing paradigms.

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IP2

Design to Manufacturing via Level Set Method

There has been a rise of research interests in two notable areas of engineering design. One is to use more high fidelity design in conceptual design stage and the other is in design for additive manufacturing. Topology optimization is a design approach that has been identified as being able to address both of these challenges. Topology optimization is a most generalized form of structural optimization that can provide an unintuitive and potentially revolutionary design solution. Many case studies quote weight saving or performance improvement in the order of 20%–80%. Topology optimization is traditionally formulated as material distribution problems where a finite element may or may not exist in the specified design domain. This discrete formulation produces a design that is fundamentally linked to the finite element representation and challenges in linking to a CAD or more traditional geometrical representation was a barrier to a wide adoption of topology optimization in the engineering design environment. The recent development of topology optimization uses the level set method which has a continuous geometry representation and together with its flexibility in topological changes, it can naturally integrate conceptual design to manufacturing. Our research group has been developing the level set topology optimization method to raise its maturity. We have also shown that the level set representation of a design eliminates the cumbersome post-processing typically required for manufacturing. The presentation will offer a perspective on the current research and the future trends of level set topology optimization.

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IP3

Power and Challenges of Simplicity

Valuable solutions to difficult problems are often based on surprisingly simple ideas. Why then did it take us so long to discover them? Possible reasons include the lack of the proper abstractions, the obsession with full generality, and the concern that some sub-problems may be insurmountable. We will illustrate this observation using examples from the speakers contributions: 3D GUI techniques for the realtime control of camera [miniCam] and free-form deformations [Twister, Bender]; compact representations for rendering [Vertex Clustering], processing [ECT, SOT, LR, Zipper] or transmitting [Topological Surgery, EdgeBreaker] triangle meshes; efficient algorithms for evaluating and rendering CSG models [Blister, CST, OBL]; effective formulations for constant [Grow&Shrink, Tightening] and variable [Relative Blending] radius rounding; and expressions for optimal in-betweening [Ball Morph] deformations or interpolating motions [Steady Affine Morph] defined by control shapes or affine transformations.

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IP4

Engineering Through Abstractions

Abstractions determine to a large extent how we relate to physical world, guiding the way we perceive, imagine, communicate, design and manufacture. In the context of computer-aided engineering, abstractions are formal models of physical artifacts, processes, and systems that give precise meaning to computer representations and algorithms. Familiar examples of abstractions in solid modeling include r-sets, orientable manifolds, constraint graphs, sweeps, and Euler operators. Recent emphasis on model-based engineering requires understanding, extending, and reconciling abstractions that include logical models to describe system's structure, various graph models to represent discrete and continuous behaviors, finite element models to simulate spatially distributed phenomena, and yet to be agreed upon models for materials, functions, and systems. The future of model-based engineering hinges on the ability to support the ever increasing diversity of abstractions in a systematic and computationally efficient manner. I will illustrate these challenges by specific examples and will propose some basic principles for addressing them.

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IP5

When Solid Modeling Stopped Being Solid: Custom Materials and Additive Processes

New fabrication processes and materials are being developed that enable products to be conceived that are well beyond anyones imagination. However, current authoring tools and design processes are not equipped to exploit these capabilities. This talk will discuss some of the short comings with the current modeling technologies and provide the motivation for the development of a new set of foundations to fully exploit the possibilities of novel fabrication processes, such as 3D printing, and materials, including carbon fiber composites.

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IP6

C^1 Isogeometric Spaces on Multipatch Geometries

One key features of isogeometric analysis is the possibility of smooth shape functions. Within each patch, smoothness up to C^{p-1} continuity is naturally achieved by p-degree splines and NURBS. However, global continuity beyond C^0 on so-called multipatch geometries poses some significant difficulties. We consider a multi-patch parametrization having G^1 continuity at the patch interfaces, and we study the behaviour of C^1 continuous isogeometric spaces under h-refinement. In general, these spaces have suboptimal approximation properties. The reason is that the C^1 continuity condition easily overconstrains the space that, in some cases, is in fact fully *locked* to zero at the patch interface. Optimal convergence is achieved under specific conditions on the geometry parametrization and spline regularity. We develop a mathematical framework and perform numerical tests, with the aim of understanding the possibilities and the rules to follow when constructing C^1 isogeometric aproximations over complex geometries. This work is in collaboration with Annabelle Collin and Thomas Takacs from the University of Pavia.

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CP0

Analytic Methods for Geometric Modeling Via Spherical Decomposition

We propose a new paradigm for more efficient computation of analytic correlations that relies on a grid-free discretization of arbitrary shapes as countable unions of balls, in turn described as sublevel sets of summations of smooth radial kernels at adaptively sampled knots. Using a simple geometric lifting trick, we interpret this combination as a convolution of an impulsive skeletal density and primitive kernels with conical support, which faithfully embeds into the convolution formulation of interactions across different objects. We provide example applications in formulating holonomic collision constraints, shape complementarity metrics, and morphological operations, unified within a single analytic framework.

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CP0

Solving the Initial Value Problem of Discrete Geodesics

Existing discrete geodesic algorithms are mainly designed for solving the boundary value problem, i.e., finding the shortest path between two given points. However, the *shortest* geodesic paths do not simulate properties of geodesics on smooth surface, for example, the *shortest* geodesic paths neither define the discrete geodesic curvature nor the parallel transport of vector fields. When a *shortest* geodesic path through a saddle vertex, it does not provide a unique solution on triangle meshes.In this paper, we focus on the initial value problem, i.e., finding a uniquely determined geodesic path from a given point in any direction. We proposed a first-order tangent ODE method for solving the initial value problem. We construct piecewise G^1 smooth surface and solve the tangent ODE in a Runge-Kutta way. The final result is obtained by projecting the path on piecewise smooth surface to the underlying mesh. Our method is different from the conventional methods of directly solving the geodesic equation (i.e., a second-order ODE of the position) on piecewise smooth surfaces, which is difficult to implement due to complicated representation of the geodesic equation involving Christoffel symbols.

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CP0

An Improved Star Test for Implicit Polynomial Objects

For a given point set, a particular point is called a star if it can see all the boundary points of the set. The star test determines whether a candidate point is a star for a given set. It is a key component of some topology computing algorithms such as Connected components via Interval Analysis (CIA), Homotopy type via Interval Analysis (HIA), etc. Those algorithms decompose the input object using axis-aligned boxes, so that each box is either not intersecting or intersecting with the object and in this later case its center is a star point of the intersection. Graphs or simplicial complexes describing the topology of the objects can be obtained by connecting these star points following different rules.

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Re-parameterization Reduces Irreducible Geometric Constraint Systems

You recklessly told your boss that solving a non-linear system of size n (n unknowns and n equations) requires a time proportional to n, as you were not very attentive during algorithmic complexity lectures. So now, you have only one night to solve a problem of big size (e.g., 1000 equations/unknowns), otherwise you will be fired in the next morning. The system is well-constrained and structurally irreducible: it doesn't contain any strictly smaller well-constrained subsystems. Its size is big, so the Newton-Raphson method is too slow and impractical. The most frustrating thing is that if you knew the values of a small number $k \ll n$ of key unknowns, then the system would be reducible to small square subsystems and easily solved. You wonder if it would be possible to exploit this reducibility, even without knowing the values of these few key unknowns. This article shows that it is indeed possible. This is done at the lowest level, at the linear algebra routines level, so that numerous solvers (Newton-Raphson, homotopy, and also p-adic methods relying on Hensel lifting) widely involved in geometric constraint solving and CAD applications can benefit from this decomposition with minor modifications. For instance, with $k \ll n$ key unknowns, the cost of a Newton iteration becomes $O(kn^2)$ instead of $O(n^3)$. Several experiments showing a significant performance gain of our re-parameterization technique are reported in this paper to consolidate our theoretical findings and to motivate its practical usage for bigger systems.

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CP0

A Total Order-Based Convex Hull Algorithm for Points in the Plane

Computing the convex hull of a set of points is a fundamental operation in many research fields, including geometric computing, computer graphics, computer vision, robotics, and so forth. This problem is particularly challenging when the number of points goes beyond some millions. In this article, we describe a very fast algorithm that copes with millions of points in a short period of time without using any kind of parallel computing. This has been made possible because the algorithm reduces to a sorting problem of the input point set, what dramatically minimizes the geometric computations (e.g., angles, distances, and so forth) that are typical in other algorithms. When compared with popular convex hull algorithms (namely, Graham's scan, Andrew's monotone chain, Jarvis' gift wrapping, Chan's, and Quickhull), our algorithm is capable of generating the convex hull of a point set in the plane much faster than those five algorithms without penalties in memory space.

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CP0

Efficient Data-Parallel Tree-Traversal for Blob-Trees

The hierarchical implicit modelling paradigm, as exemplified by the BlobTree, makes it possible to support not only Boolean operations and affine transformations, but also various forms of blending and space warping. Typically, the resulting solid is converted to a boundary representation, a triangle mesh approximation, for rendering. These triangles are obtained by evaluating the corresponding implicit function (field) at the samples of a dense regular three-dimensional grid and by performing a local iso-surface extraction at each voxel. The performance bottleneck of this rendering process lies in the cost of the tree traversal (which typically must be executed hundreds of millions of times) and in the cost of applying the inverses of the space transformations associated with some of the nodes of the tree to the grid samples. Tree pruning is commonly used to reduce the number of samples for which the field value must be computed. Here, we propose a complementary strategy, which reduces the costs of both the traversal and of applying the inverses of the blending and warping transformations that are associated with each evaluation. Without blending or warping, a BlobTree can be reduced to a CSG tree only containing Boolean nodes and affine transformations, which can be reordered to increase memory coherence. Furthermore, the cumulative effects of the affine transformations can be precomputed via matrix multiplication. We propose extensions of these techniques from CSG trees to the fully general BlobTrees. These extensions are based on tree reordering, bottom-up traversal, and caching of the combined matrix for uninterrupted runs of affine transformations in the BlobTree. We show that these new techniques result in an order of magnitude performance improvement for rendering large BlobTrees on modern Single Program Multiple Data (SPMD) devices.

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CP0

Consistent Quadrangulation for Shape Collections Via Feature Line Co-Extraction

This paper presents a method that takes as input a collection of 3D surface shapes, and produces a consistent and individually feature preserving quadrangulation of each shape. By exploring the correspondence between shapes within a collection, we coherently extract a set of representative feature lines as the key characteristics for the given shapes. Then we compute a smooth cross-field interpolating sparsely distributed directional constraints induced from the feature lines and apply the mixed-integer quadrangulation to generate the quad meshes. With the aim of aligning the quad-meshing results in a common parametric domain, we develop a greedy algorithm to extract aligned cut graphs across the shape collection.

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CP0

Precise Contact Motion Planning for Deformable Planar Curved Shapes

We present a precise contact motion planning algorithm for a deformable robot in a planar environment with stationary obstacles.

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CP0

Effective Contact Measures

Contact area is an important geometric measurement in many physical systems. It is also difficult to compute due to its extreme sensitivity to infinitesimal perturbations. In this paper, we propose a new concept called an effective contact measure, which acts as a smooth version of contact area. Effective contact measures incorporate a notion of scale into the definition of contact area, allowing one to consider the degree of contact at different sizes. We show how effective contact measures can yield useful statistics for a number of applications, including analysis of multiphase materials and docking/alignment problems.

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CP0

Automatic Generation of Lego Building Instructions from Multiple Photographic Images of Real Objects

We introduce a system to reconstruct large scale LEGO models from multiple two dimensional images of objects taken from different views. We employ a unit voxel with an edge length ratio of 5:5:6 for the shape from silhouette method that reconstructs an octree voxel-based three dimensional model with color information from images. We then convert the resulting voxel model with color information into a LEGO sculpture. In order to minimize the number of LEGO bricks, we use a stochastic global optimization method, simulated annealing, to hollow the model as much as possible but keep its strength for portability. Several real complex LEGO models are provided to demonstrate the effectiveness of the proposed method.

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CP0

Isogeometric Segmentation: Construction of Auxiliary Curves

In the context of segmenting a boundary represented solid into topological hexahedra suitable for isogeometric analysis, it is often necessary to split an existing face by constructing auxiliary curves. We consider solids represented as a collection of trimmed spline surfaces, and design a curve which can split the domain of a trimmed surface into two pieces satisfying the following criteria: the curve must not intersect the boundary of the original domain, it must not intersect itself, the two resulting pieces should have good shape, and the endpoints and the tangents of the curve at the endpoints must be equal to specified values.

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CP0

Generalizing Bicubic Splines for Modelling and Iga with Irregular Layout

Quad meshes can be interpreted as tensor-product spline control meshes as long as they form a regular grid, locally. We present a new option for complementing bi-3 splines by bi-4 splines near irregularities in the mesh layout, where less or more than four quadrilaterals join. These new generalized surface and IGA (isogeometric analysis) elements have as their degrees of freedom the vertices of the irregular quad mesh. From a geometric design point of view, the new construction distinguishes itself from earlier work by a notably better distribution of highlight lines. From the IGA point of view, increased smoothness and reproduction at the irregular point yield fast convergence.

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CP0

A Statistical Atlas Based Approach to Automated Subject-Specific Fe Modeling

Subject-specific modeling is increasingly important in biomechanics simulation. However, how to automatically create high-quality finite element (FE) mesh, and how to automatically impose boundary condition are challenging. This paper presents a statistical atlas based approach for automatic meshing of subject-specific shapes and automatic transferring of boundary conditions onto the resulting meshes. In our approach, shape variations among a shape population are explicitly modeled and the correspondence between a given subject-specific shape and the statistical atlas is sought within the "legal" shape variations.

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CP0

Average Curve of N Smooth Planar Curves

We define the Average Curve(AC) of a compatible set of two or more smooth and planar, Jordan curves. It is independent of their order and representation. We compare two variants: the valley AC(vAC), defined in terms of the valley of the field that sums the squared distances to the input curves, and the zero AC(zAC), defined as the zero set of the field that sums the signed distances to the input curves. Our formulation provides an orthogonal projection homeomorphism from the AC to each input curve. We use it to define compatibility. We propose a fast tracing algorithm for computing a polygonal approximation (PAC) of the AC and for testing compatibility.

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CP0

Surgem: A Solid Modeling Tool for Planning and Optimizing Pediatric Heart Surgeriem

Approximately 1% of children are born with a moderate to severe congenital heart defect, and half of them undergo one or more surgeries to fix it. SURGEM, a solid modeling environment, is used to improve surgical outcome by allowing the surgeon to design the geometry for several possible surgical options before the operation and to evaluate their relative merits using computational fluid simulation. We describe here the solid modeling and graphical user interface challenges that we have encountered while developing support for three surgeries: (1) repair of double-outlet right ventricle, which adds a graft wall within the cardiac chambers to split the solid model of the unique ventricle, (2) the Fontan procedure, which routes a graft tube to connect the inferior vena cava to the pulmonary arteries, and (3) stenosis repair, which adds a stent to expand a constricted artery.

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CP0

Statistical Geometric Computation on Tolerances for Dimensioning

Dimensions are used to specify the distances between different features in geometric models. These dimensions will often be expressed as a range of allowable dimensions. When considering a group of toleranced dimensions, these ranges can be analyzed as either a worst-case bound on allowable ranges, or as a statistical measure of expected distribution. This paper presents a new geometric model for representing statistically-based tolerance regions. Methods for tolerance estimation and allocation on a geometric model are provided by generalizing root sum square (RSS) methods for compositing and cascading over tolerance zones. This gives us a geometric interpretation of a statistical analysis. Tolerance regions are determined by probabilities of variations of dimensions falling into the region. A dependency graph over dimensions can be represented by a topological graph on which the tolerance cascading and tolerance allocation can be processed.

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CP0

Secondary Laplace Operator and Generalized Giaquinta-Hildebrandt Operator with Applications on Surface Segmentation and Smoothing

Various geometric operators have been playing an important role in surface processing. For example, many shape analysis algorithms have been developed based on eigenfunctions of the Laplace-Beltrami operator (LBO), which is defined based on the first fundamental form of the surface. In this paper, we introduce two new geometric operators based on the second fundamental form of the surface, namely the secondary Laplace operator (SLO) and generalized Giaquinta-Hildebrandt operator (GGHO). Surface features such as concave creases/regions and convex ridges can be captured by eigenfunctions of the SLO, which can be used in surface segmentation with concave and convex features detected. Moreover, a new geometric flow method is developed based on the GGHO, providing an effective tool for sharp feature-preserving surface smoothing.

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CP0

Efficient Global Penetration Depth Computation for Articulated Models

We present an algorithm for computing the global penetration depth between an articulated model and an obstacle or between the distinctive links of an articulated model. In so doing, we use a formulation of penetration depth derived in configuration space. We first compute an approximation of the boundary of the obstacle regions using a support vector machine in a learning stage. Then, we employ a nearest neighbor search to perform a runtime query for penetration depth. The computational complexity of the runtime query depends on the number of support vectors, and its computational time varies from 0.03 to 3 milliseconds in our benchmarks. We can guarantee that the configuration realizing the penetration depth is penetration free, and the algorithm can handle general articulated models. We tested our algorithm in robot motion planning and grasping simulations using many high degree of freedom (DOF) articulated models. Our algorithm is the first to efficiently compute global penetration depth for high-DOF articulated models.

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CP0

Geometric Characteristics of a Class of Cubic Curves with Rational Offsets

Planar Bezier curves that have rationally parameterized offsets can be classified into two classes. The first class is composed of curves that have Pythagorean hodographs (PH) and the second class is composed of curves that do not have PHs but can have rational PHs after reparameterization by a fractional quadratic transformation. This paper reveals a geometric characterization for all properly-parameterized cubic Bezier curves in the second class. The characterization is given in terms of Bezier control polygon geometry. Based on the derived conditions, we also present a simple geometric construction of G^1 Hermite interpolation using such Bezier curves. The construction results in a one parameter family of curves if a solution exists. We further prove that there exists a unique value of the parameter which minimizes the integral of the squared norm of the second order derivative of the curves.

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CP1

Peicewise Bézier Surfaces over Unstructured Quadrilateral Meshes

Given polynomials of order n and the corresponding Bézier tensor product patches over an unstructured quadrilateral mesh with vertices of any valence, find a solution to the $G^1 1$ or $C^1 1$ approximation (resp. interpolation) problem and the corresponding minimal determining set. We show that there is always a solution for $n \geq 5$ and under some restrictions for $n = 4$. Domains with cubic boundary curve are considered. Application to approximation or PDE solutions are given.

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CP1

Support Vector Machines for Knot Placement in B-Spline Surface Approximation

We present an algorithm to place the knots for B-spline surface approximation based on a machine-learning approach. A pre-trained support vector machine (SVM) is used to compute an optimal knot-vectors with respect to the surface shape. This SVM is then used to improve the averaging technique by Piegl and Tiller [Piegl, Les A., and Wayne Tiller. "Surface approximation to scanned data." The visual computer 16.7 (2000): 386-395.]. Experimental results show the performance of our algorithm for the approximation of B-Spline surfaces.

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CP1

Stable Simplex Spline Bases for C3 Quintics on the Powell-Sabin 12-Split

For the C^3 quintics on the Powell-Sabin 12-split of a triangle, we determine explicitly the six symmetric simplex spline bases that reduce to a B-spline basis on each edge, have a positive partition of unity, a Marsden identity that splits into real linear factors, and an intuitive domain mesh. The bases are stable in the L_∞ norm, have a quasi-interpolant with approximation order 6, and other B-spline-like properties.

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CP1

Slices of 3D Surfaces on the Web Using Tensor Product B-Spline Grids

The generation of cutting planes, or slices of function surfaces, is the most unique feature available to users accessing the 3D visualizations in the NIST Digital Library of Mathematical Functions (DLMF). While the feature was difficult to implement and the source of many portability problems, the use of structured tensor product grid generation techniques helped us create code capable of handling complicated multi-connected function domains. We discuss the work and show DLMF examples.

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CP1

Curves with Quadratic Logarithmic Curvature Graphs

In this talk, we propose a new kind of curves which are curves with quadratic logarithmic curvature graphs (QLCG curves). The QLCG curves can be derived by extending log-aesthetic curves[Yoshida & Saito, Interactive Aesthetic Curve Segments, Visual Computer, 2006], which are curves with linear logarithmic curvature graphs (LCGs). To formulate QLCG curves, we add the second degree coefficient γ in the LCG, where curves with $\gamma = 0$ are log-aesthetic curves. We provide equations for drawing the curves and analyze the fundamental characteristics. In comparison with log-aesthetic curves, the proposed curves have following advantages: additional parameter γ for controlling the curve and curves with $\gamma < 0$ have finite arc lengths, and points with 0 and infinite curvature without depending on other parameters.

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CP1

Truncated B-Splines for Non-Nested Refinement

Various approaches to extend the construction of tensor-product splines have been introduced in order to allow for adaptive refinement in modeling and/or simulations. Our framework is based on truncated hierarchical (TH)B–splines due to their good mathematical properties. We generalize THB–splines in order to allow for using non-nested spline spaces to represent different parts of the model. In particular, we show how to define a spline basis that forms a non-negative partition of unity.

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CP2

IgA-Based Solver for Turbulence Modelling on Multipatch Geometries

In this talk, we focus on turbulence modelling with the help of isogeometric analysis based on NURBS objects. We implemented a solver for Reynolds-Averaged Navier-Stokes equations complemented by k-ω model. The solver is intended to run on complex geometries, which cannot be described by one NURBS object. Thus, it is necessary to consider multipatch NURBS domains, which are handled by discontinuous Galerkin method in our solver. The results will be demonstrated on standard benchmark problems.

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CP2

Nurbs Models and Volumetric Parameterizations of Water Turbines

In this talk, we focus on creation of parametric geometric models of different water turbines and their volumetric parameterizations based on NURBS objects which are commonly used in current CAD/CAM systems. Such models can be used for the consequent computations based on isogeometric analysis (IGA), especially for flow modelling in our case. Combination of IGA-based simulations with high-quality parametric geometric models can serve as a common base for (semi-)automatic shape optimization methods for water turbines.

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CP2

A New One-Sided Spline Filter for Discontinuous Galerkin Solutions on Domains with Boundary

Post-convolving the output of Discontinuous Galerkin computations with symmetric spline filters is known to improve both smoothness and accuracy – except near domain boundaries. To obtain solutions whose accuracy near the boundary is as good as in the interior, we leverage recently-developed one-sided filters with multiple knots to increase the dimension of the filter's spline space but not its support. We present simple explicit formulas for the filter coefficients.

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CP2

Steady-State and Dynamical Radially-Symmetric Solutions of 2D Nonlinear Viscoelasticity

We treat the initial-boundary-value problems for the radial motions of nonlinearly viscoelastic annular plates and spherical shells of strain-rate type, which are described by the geometrically exact 2D theory. The governing equation is a second-order quasilinear parabolic-hyperbolic PDE in one space variable. In the first part of our work, we study the steady-state solutions of our problem by employing several mathematical tools, each of which has different strengths and weaknesses for handling intrinsic diffculties in the mechanics. In the second part, we study the dynamical solutions of our problem. We first introduce a set of constitutive hypotheses which ensure that solutions are unique, exist for all time, and depend continuously on the data. We then exhibit alternative conditions on the constitutive functions and on the boundary terms ensuring that there are globally defined unbounded solutions and there are solutions that blow up in finite time.

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CP2

Adaptively Weighted Numerical Integration in the Finite Cell Method

In this talk, we will demonstrate the application of our newly developed integration scheme called the Adaptively Weighted (AW) numerical integration scheme in the context of the Finite Cell Method which must perform numerical integration over arbitrary domains without meshing. Unlike traditional approaches to integration, in AW scheme, the quadrature weights directly adapt to the complex geometric domain. We demonstrate the computational efficiency of AW over traditional adaptive integration schemes in two and three dimensions.

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CP3

2D Packing of Large Size Non-Rectangular Quad Items into Smaller Size Polygonal Bins

A greedy technique for packing of large size non-rectangular items into smaller size polygonal bins is outlined. Several quad regions (packable regions) are produced from polygonal bins. Packed items can be larger than packable regions some of whose portions can exceed the bin. After substraction of the packed item from the packable region, polygonal shapes can be formed. Split algorithm decomposes such shapes into quad items each of which will be processed independently during packing.

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CP3

Reconstruction and Design of Functionally Graded Material Structures

We propose to represent and control material properties of FGM using the notion of material descriptors which include common geometric, statistical, and topological measures. In particular, Minkowski functionals are widely believed to correlate with mechanical properties of many materials, including bone. Building on ideas from texture synthesis, we formulate the problem of design and (re)construction of FGM structure as a process of selecting neighborhoods from an FGM exemplar, based on target material descriptor fields. We identify the necessary conditions on the target descriptor field to be compatible with the exemplar, and discuss how this conditions can be verified and enforced. The effectiveness of the proposed method in generating a smooth and continuously varying structure of FGM with guaranteed properties is demonstrated by two examples: bone structure reconstruction and design of a functionally graded bone structure.

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CP3

Interpolation and Shape Preserving Design with Hyperbolic Spaces

In this paper we focus on hyperbolic spaces generated by algebraic polynomials, the hyperbolic sine and cosine. The analysis of these spaces leads to constructions that can be reduced to Hermite interpolation problems. We present classical interpolation formulae, such as Newton and Aitken-Neville formulae and a suggestion of implementation. We also express the Hermite interpolant in terms of polynomial interpolants and derive practical error bounds. Applications to shape preserving curve design are also shown.

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CP3

On Developable Surfaces in Dental Imaging

We report on recent work on the use of developable splines in the context of exploration of medical volumes. Ruled developable patches over Bzier curves have been introduced by Aumann in 2003 and later extended to B-splines by Fernndez-Jambrina. We consider G1 splines constructed over Catmull-Rom splines of degree three and cone splines over circle splines and compare both techniques. We also look at the planar isometric unfoldings of both types of splines.

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CP3

A Parallel Hash Map for Level-of-Detail-Aware Depth-Map Fusion

We introduce a real-time, memory-efficient method for depth-map fusion and LOD-aware spatial data storage. Image-space reconstruction methods result in a set of view-dependent depth-maps. So, an additional depth-map fusion mechanism in combination with a spatial data storage scheme is used to assemble and store the models. Our approach guarantees memory efficiency by using a hash map approach that can distinguish different data LOD depending on the data resolution of the input depth-maps. It is better suited for modern GPU than tree-based data structures and allows for efficient iterative data updates. The described depth-map fusion method is optimized for massive parallel processing which enables real-time performance. It is designed for tight interaction with the storage system without inefficient CPU interference. An evaluation of the parallel hash-map and the fusion method demonstrates the benefit of our approach for the depth-map fusion and spatial data storage problem.

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CP4

Crystal Growth Shapes in Bond-Counting Models and Continuum Models

When continuum methods are used to model crystal growth, typically an anisotropic surface energy function is selected. We determine the relationship between a crystal's lattice structure, surface energy, and growth shape. Comparing models, we demonstrate that not all growth shapes seen in continuum models are recreatable in bond-counting models. Specifically, we determine that a 12-armed dendrite as modeled in Haxhimali et al. is not a possible growth shape using a bond-counting model under reasonable parameters.

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CP4

Multi-Resolution Geometrical Models of Mammalian Tissues

Understanding mammalian tissue structure and function requires the quantitative monitoring of cellular processes from the molecular to the tissue scale and consequently a geometrical model of the tissue, i.e. an accurate 3D digital representation of the cells forming the tissue with subcellular resolution. We developed an adjustable pipeline for reconstructing geometrical models of tissues from microscopy images covering multiple scales ($1\mu m \div 1mm$) and applied it to the quantitative analysis of liver, kidney and lung tissue.

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CP4

Blind Reconstruction of a Single-Source Signal from Its Multi-Reflected Data in a Convex Polygonal Room

A new iterative method for the reconstruction of the original signal from multi-reflected signals is proposed and applied to typical cases where a single-source sound is multi-reflected by the room walls, under the assumption that the locations of observation points are known, while the original signal and the locations of the source point and the room walls are unknown. Fairly good results are obtained for the identification of the original signal and the wall locations.

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CP4

Multi-resolution Method for Co-propagating High Intensity Pulses

Laser filamentation is an area of research that provides a unique challenges in applied mathematics, physics, computer science and engineering. In this talk I will describe the (3+1)D model of co-propagating nanosecond and femtosecond pulses in air and present the resolution technique that allows to capture all important effects on different time scales.

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CP4

Anamorphosis Made Simple; Impossible Objects

Made Possible

We have developed a simple method to create a digital anamorphosis, using a rational FFD (Free-Form Deformation). The key idea is to employ homogeneous coordinates with origin at the viewpoint, and then deform the object with a rational Bézier hyperpatch. In a typical anamorphosis, an object appears distorted unless viewed from a particular viewpoint. However, with a clever design, it is also possible to create geometry that look impossible when viewed from a certain viewpoint.

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CP4

Tree Representations of Streamline Topologies of Structurally Stable 2D Hamiltonian Vector Fields

We show that the streamline topologies of generic Hamiltonian flows in 2D multiply connected domains are in one-to-one correspondence with rooted, labelled and directed plane trees. We also show that a symbolic expression, called a regular expression, is uniquely assigned to each generic streamline topologies. Computationally, it allows us to convert a complex pattern data of a given streamline topology into a simple symbolic text data easily handled by computers.

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MS1

Composite Design Primer

Abstract not available.

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MS1

Composite Analysis

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MS1

Future Vision of Advanced Materials and Processes in Design

Abstract not available.

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MS1

Composite Manufacturing

Abstract not available.

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MS2

A New Basis for PHT-Splines

In this talk, we propose a new basis consisting of a set of local tensor product B-splines for PHT-splines which overcomes the decay phenomenon of the original basis functions. Some examples are provided for solving numerical PDEs with the new basis, and comparison is made between the new basis and the original basis. Experimental results suggest that the new basis provides better numerical stability in solving numerical PDEs.

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MS2

Hybrid Volume Completion with Mixed-Order Bézier Elements

A methodology to create a hybrid volumetric representation from a 2-manifold without boundaries represented with untrimmed tensor product B-spline surfaces is presented. Near the boundary are trivariate tensor product B-splines with unstructured mixed-order Bézier tetrahedral elements in the interior of the object set to require C^0 smoothness across their interfaces. Our approach to constructing stiffness and mass matrices C^0 smoothness is automatically maintained when performing computer graphics simulations, representing material properties, or performing isogeometric analysis

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MS2

On Analysis Suitable T-Splines in Any Dimension

Traditionally, T-splines have been constructed from the topology of the control mesh. From this perspective, properties of the spline space are hard to study and to generalize to arbitrary degree and dimension. We follow a similar approach to that of [Dokken et al, Polynomial splines over locally refined box-partitions, 2013] and propose a local refinement rule, that, by construction, maintains all important properties of univariate B-splines, such as local linear independence, partition of unity, etc. Moreover, our approach is independent of the spatial dimension and works for all polynomial degrees.

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MS2

Bézier Projection and Applications

In this talk well describe Bézier projection. Bézier projection is an optimally accurate local projection scheme based on Bézier extraction. The approach can be applied to both T-splines, nonuniform rational B-splines, and their hierarchical extensions. We will discuss various ways the projection scheme can be used in design and analysis. In particular, well discuss its use in local adaptivity, weakly continuous geometry, and higher-order accurate explicit structural dynamics.

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MS3

Fast, Approximate and Scalable Geometric Optimization (Big Data and High Dimensional Spaces)

Geometric optimization is used to solve a variety of image, model matching, selection and ranking problems (e.g. deformable shape similarity, drug screening, assembly prediction) . The optimization functionals are multi-Dim correlation integrals while the search space is the high-Dim product of deformable transformations. In this talk I shall consider methods to combat the curse of high dimensionality via the JL lemma, and also achieve accuracy-speed tradeoffs for Big data using low-discrepancy samplings and non-uniform FFT.

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MS3

Modelling Geometrical Big Data Using Locally Refined B-Splines

LRB-spline approximation can be considered the geometrical equivalent of jpeg compression, with a high compression rate in smooth areas. Its approximation of point clouds gives a good rate of compression for surfaces, and we expect the compression to be even more significant for approximations of volumes and higher-dimensional data. In this presentation we present results from the EU-funded projects VELaSSCo and IQmulus, using LRB-splines to model big data, e.g., terrain and simulation datasets from Particle Element Methods.

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MS3

Synchronous Visual Analytics on Petabytes of Molecular Simulations-Topology, Geometry and Numerics

We present the integration of topological and numeric algorithms for synchronous visualization of the petabyte output from high performance computing molecular simulations. Techniques are invoked from knot theory for timely warning of potential self-intersections. These self-intersections are of interest to the domain scientists. The topological methods provide performance and reliability advantages over purely geometric techniques for the dynamic visualizations produced.

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MS3

Geometric Processing in Statistical Shape Modeling

In this presentation, we present the workflow of geometric processing procedures toward statistical modeling and analysis of biomedical shapes across a population. The input is a collection of CT images or discrete 3D models from a set of subjects. We seek a statistical description of shape variation across the population that can be useful for statistical inference. A B-spline based direct diffeomorphic reparameterization technique for improving shape correspondence across the population will be presented.

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MS4

Issues and Experiences Implementing Cloud-based

CAD

Our company supplies a solid modeling kernel to customers who produce various types of CAD systems, and those CAD system developers are doing some interesting forward-looking development. I will discuss the activities of one customer who is putting their CAD system on the "cloud" - they are obviously not the only ones doing this, but their experiences and requirements are interesting. They have designed a protocol to communicate in a simple manner between server and client. They are also working on enhancing their GPU parallelization, which allows tessellation to be done locally on the client, greatly reducing the amount of data that must be transferred.

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MS4
Design and Simulation in the Cloud

The I4MS initiative http://i4ms.eu/ in EU's Public-Private Partnership for Factories of the Future addresses HPC Cloud services for engineering and manufacturing industries. One of the I4MS-projects, CloudFlow http://www.eu-cloudflow.eu/ addresses solution oriented workflows in the Cloud in three waves of Experiments. The CAxMan project "Computer Aided Technologies for Additive Manufacturing" (2015-2018, in June 2015 in contract negotiations), will use the CloudFlow infrastructure to make workflows for design, simulation, process planning and process simulation for additive manufacturing.

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MS4
Scripted Geometry Processing for Manufacturing

Manufacturing process planning frequently requires complex geometric computations to be performed. Milling requires tool path generation while composite tape deposition requires calculation of geodesics and geodesic offsets. Frequently, the calculations required are specific to particular combinations of machine tool, part, and tool tip. Moreover, achieving high performance can lead to complex trajectory optimization problems. This talk presents a general framework for organizing these computations so that they can be scripted in very high-level ways.

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MS4
Pre- and Post- Design - The Future of Geometric Modeling?

As the importance of the digital model spreads throughout PLM the number of representations has become a Tower of Babel. Isogeometric analysis is our version of Esparanto. I will propose an alternative modeling "language" which will allow designers to work in their own dialect but present their model in "English" to the rest of the PLM world. Because these models have huge amounts of data interacting with them efficiently requires blending computer science techniques with geometric insight. I will give both successful and potential examples.

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MS5
Free Surface Hydrodynamics Using Isogeometric Analysis

The objective of the present work is to develop an efficient and accurate model for gravitational free surface water waves using isogeometric analysis. We consider the discretization of a set of fully nonlinear potential flow equations that can account for dispersive wave propagation and wave-wave interactions in coastal and offshore areas, and take into account varying bathymetry. The model uses a flexible discretization method based on tensor-product NURBS/B- splines for exact representation of geometric structures and smooth approximation of the flow. The model also provides a basis for accurate kinematics calculations that are of relevance to accurate estimation of peak loads in wave-structure interactions. In this talk, we describe the fundamentals of the proposed isogeometric free surface hydrodynamical model, show some preliminary results on analysis of accuracy, and compare these to results obtained using a recently developed state-of-the-art spectral element model using C0 continuous basis functions. The analysis highlights properties and differences of the methodologies.

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MS5
Discrete Surface Uniformization, Theory and Algorithms

Surface uniformization theorem plays a fundamental role in surface differential geometry, which states that any Riemannian metric on a closed surface can be conformally deformed to the one with constant Gaussian curvature. In this talk, the uniformization theorem is generalized to the discrete surfaces. The proofs for the existence, uniqueness of the solution will be explained. When the tessellation is refined, the discrete uniformization converges to the smooth solution. The computational algorithms will be explained, and some applications will be demonstrated.

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MS5
Isogeometric Analysis for Wave-Body Interaction Problems

This presentation will deliver a critical review of our work in the area of Isogeometric Boundary Element Methods (BEM) for wave-body interaction problems involving 2D/3D bodies (wing, ships) moving underneath or on the free surface of an ideal (inviscid, incompressible and irrotational) liquid. In this context, the performance (e.g., rate of convergence) of in-house developed NURBS- and T-splines-based isogeometric collocated BEM solvers will be illustrated in conjunction with CATIA- and Rhino3D-based parametric modelers for optimization purposes.

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MS5

Hierarchical Spline Quasi-Interpolation

We present a general and simple procedure to construct quasi-interpolants in hierarchical spaces. Such spaces are composed of a hierarchy of nested spaces and provide a flexible framework for local refinement. The proposed hierarchical quasi-interpolants are described in terms of the so-called truncated hierarchical basis. Quasi-interpolants of full approximation order and/or projections can be easily obtained. The main ingredient of the construction is the property of preservation of coefficients of the truncated basis representation.

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MS6

High-Quality Anisotropic Surface Meshing

Abstract not available.

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MS6

Computing Intrinsic Delaunay Triangulations on Polyhedral Surfaces

Delaunay triangulation is a fundamental data structure and has tremendous applications in many engineering fields. Although Delaunay triangulations in Euclidean spaces are well studied and understood, computing intrinsic Delaunay triangulations on polyhedral surfaces has received much less attention. In this talk, we will present a new method for constructing IDTs on manifold triangle meshes. Based on the duality of geodesic Voronoi diagrams, our method can guarantee the resultant IDTs are strongly regular. Our method is non-iterative so that its performance is insensitive to the number of non-Delaunay edges. It has a theoretical $O(n^2 \log n)$ time complexity, where n is the number of mesh vertices. Empirically, it runs in linear time $O(n)$ on real-world models.

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MS6

A Spectral Method for Anisotropic Quad Meshing

Abstract not available.

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MS6

Geodesic-Based Shape Descriptors

Abstract not available.

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MS7

Bounding Volume Hierarchies for Planar Freeform Curves

We present several different ways of generating bounding volumes for planar freeform curves and compare their relative performance in computing time and storage space. In particular, we focus on the curve approximation methods with cubic convergence and the general case where the given planar curves may change their shape dynamically. We also demonstrate the effectiveness of these construction methods using a few test examples of real-time algorithms implemented for planar freeform curves.

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MS7

Hierarchical Data Structures for Freeform Geometric Models

Hierarchical data structure is one of the most widely adapted data structures for the distance related computation. Algorithms based on the hierarchical data structure often show significant performance improvement over nave approaches. However, there are only limited numbers of previous works on hierarchical data structures for the freeform NURBS surfaces. In this talk, we discuss technical difficulties in developing hierarchical data structures for NURBS surfaces and introduce several approaches to tackle this problem.

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MS7

Covering 2D Domains Using Random Curves

Covering a given $2D$ domain D with a random curve, C,

has, for example, applications in artistic manufacturing/3D printing. D is considered covered if $\forall p \in D,\ dist(p, C) < \epsilon$. Our distance bound approach computes the complete set of local distance extrema. This involves computing binormals and circles co-tangent to three points of C, etc. A constructive algorithm is then proposed to iteratively create C for convex domains. Examples will be presented.

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MS7

Gpu Approaches to Distance Calculations for Freeforms

We compare sample-based approaches that exploit the massive data parallelism of GPUs for accelerating distance calculations for freeforms. We discuss how to calculate accuracy bounds both for parallel numerical iteration and axis-aligned bounding-box hierarchy approaches, dependent on the sampling as well as the curvature of the surfaces. We discuss implementation decisions and tradeoffs, and the advantages and disadvantages of numerical iteration versus parallel hierarchical culling methods. (Joint work with Iddo Hanniel and Adarsh Krishnamurthy.)

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MS8

Weighted T-spline and Its Application in Isogeometric Analysis

To facilitate isogeometric analysis, we present weighted T-spline here, which introduces a weighting idea to T-spline basis functions. Weighted T-spline basis functions satisfy partition of unity and are linearly independent. Less geometrical constraint is applied to the T-mesh, and the number of control points can be decreased. Weighted T-splines are applied to reparameterize trimmed NURBS patches and handling extraordinary nodes, demonstrating that it can generate complicate models for isogeometric analysis.

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MS8

A Numerical Evaluation of Convergence Properties of Unstructured T-splines in Extraordinary Regions for Isogeometric Analysis

T-splines have been widely studied in recent years as one of the important schemes for isogeometric analysis. They possess important properties of local refinements with similar convergence properties to NURBS. This talk presents a numerical evaluation of convergence properties of unstructured T-splines in extraordinary regions for isogeometric analysis. The results are systematically evaluated for a set of standard geometry stencils representing physical domains against a class of scaled target functions representing different underlying field solutions.

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MS8

Splines on Regular Triangulations in Isogeometric Analysis

Bivariate box splines are splines which can be defined on regular triangulations and can be seen as a natural bivariate generalization of univariate B-splines. They can be easily extended to higher dimensions. Therefore, they constitute an intermediate step between tensor product splines and splines on general triangulations, and can provide an interesting tool in IgA. In this talk we discuss some preliminaries about the use of suitable box splines in IgA.

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MS8

Iga on Generalized 3-Direction Triangulations

The talk explains isogeometric analysis with C1 elements on 3-direction triangulations enriched by non-6-valent vertices.

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MS8

Isogeometric Analysis and Shape Optimization on Triangulations

In this talk, I will present our recent work on isogeometric analysis using rational Triangular Bezier Splines (rTBS). In this approach, both the geometry and the physical field are represented by multivariate splines in Bernstein Bezier form over a triangulation of the domain. Numerical examples for both two-dimensional and three-dimensional problems will be presented. Optimal convergence rates for both C^0 and C^r elements have been obtained. Its application in shape optimization will also be presented.

Xiaoping Qian

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MS9

Smooth k-Vector Fields, k-Measures and Their Boundary

I introduce the boundary of (compactly supported) smooth k-vector fields as primary, and define the exterior derivative of differential k-forms via an integral duality. This is nicely consistent with the way in which boundary and coboundary are introduced in algebraic topology and discrete exterior calculus. The notion of boundary of k-vector fields extends naturally to general k-measures. Then, identifying each k-dimensional submanifold with boundary with the corresponding characteristic k-measure reconciles the different notions of boundary.

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MS9

Computing Harmonic Forms

To solve Poisson's equations for differential forms harmonic forms or fields must be computed. These spaces are needed to make Poisson's equation well-posed. For closed manifolds harmonic k-forms space is isomorphic to k-dimensional cohomology. For manifolds with boundary harmonic k-fields space is isomorphic to k-dimensional relative or absolute cohomology. Thus computation of harmonic forms is a very natural area of interaction between topology and physical problems.

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MS9

LAR: a Novel Representation Scheme of Geometric-Topological Data

This talk points out the design goals of Linear Algebraic Representation (LAR), a novel representation of big geometric-topological data, characterized by a large domain, encompassing 2D and 3D meshes, manifold and non manifold geometric and solid models, and high-resolution 3D images. We aim to demonstrate its simplicity and effectiveness. It is being used in disparate applications, including the extraction of models of liver portal system and building modeling for indoor mapping and loT.

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MS9

Compatibility Equations of Nonlinear Elasticity for Non-Simply-Connected Bodies

We discuss the necessary and sufficient compatibility equations of nonlinear elasticity for non-simply-connected bodies when the ambient space is Euclidean. We show that the necessary and sufficient conditions for compatibility of deformation gradient is vanishing of its exterior derivative and all its periods, i.e. its integral over generators of the first homology group of the material manifold. We will show that not every non-null-homotpic path requires supplementary compatibility equations. We then find the necessary and sufficient compatibility conditions for the right Cauchy-Green strain tensor for non-simply-connected bodies when the material and ambient space manifolds have the same dimensions. We discuss the well-known necessary compatibility equations in the linearized setting and the Cesaro-Volterra path integral. We then obtain the sufficient conditions of compatibility for the linearized strain when the body is not simply-connected.

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MS10

Compact Kronecker Representation of Isogeometric Matrices for Fast Integration

In tensor-product B-spline isogeometric simulations in d spatial dimensions, the problem size n^d is multiplied by a factor of 2^d upon each uniform $h-$refinement. Moreover, memory requirements and computation time for matrix generation are of order $O(n^d p^d)$ and $O(n^d p^{3d})$, respectively. To overcome this "curse of dimensionality" we derive a compact Kronecker product decomposition of the mass and stiffness matrices. As a result, multi-dimensional integration is conveniently reduced to univariate integration. The previous costs become $O(Rdnp)$ and $O(Rdnp^3)$ respectively, where the constant R depends on how complex the computational domain is.

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MS10

Efficient Quadrature Algorithm and Trimmed Geometries

We discuss the sum-factorization approach for the calculation of the integrals on trimmed domains. Within the standard element-by-element assembling paradigm, we reparametrize trimmed elements up to machine precision by tensor-product patches and then take advantage of the tensor-product structure to reduce the quadrature computational cost from $O(Np^{3d})$ to $O(Np^{2d+1})$, where p is the polynomial degree, d is the dimensionality and N the number of mesh elements.

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MS10

Efficient Quadrature for High Degree Isogeometric Analysis

In this talk we present a result on the computation of the linear system arising in the Galerkin isogeometric method. The main interest are the cases where the degree of the approximation is raised, so that the computational cost in assembling become challenging. With a change of paradigm in the quadrature procedure, we obtain a procedure that is ready for parallel implementation and is more efficient compared to the other approaches known in literature. These results are new and are part of a work in progress.

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MS10

Truncated Hierarchical Catmull-Clark Subdivision with Local Refinement

We present a new method termed Truncated Hierarchical Catmull-Clark Subdivision (THCCS), which generalizes THB-splines to control grids of arbitrary topology. THCCS basis functions satisfy partition of unity, are linearly independent, and are locally refinable. THCCS also preserves geometry during adaptive h-refinement and thus inherits the surface continuity of Catmull-Clark subdivision. Recently, we extended THCCS to improve the efficiency of local refinement in THCCS, which is demonstrated by several numerical tests.

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MS11

4D Printing for Freeform Surfaces: Design Optimization of Origami and Kirigami Structures

A self-folding structure fabricated by additive manufacturing can be automatically folded into a demanding 3D shape by actuation mechanisms such as heating this is also called 4D printing. However, 3D surfaces can only be fabricated by self-folding structures when they are flattenable. Most generally designed parts are not flattenable. To address this problem, we develop a shape optimization method to design self-folding structures in 4D printing.

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MS11

Adaptive and Robust Slicing of Scan Data for Additive Manufacturing

In this talk, I will overview a moving least-squares (MLS) surface based approach for processing scan data for additive manufacturing applications. It slices MLS surfaces into planar contours. The resulting layer thickness and layer contours are adaptive to local curvatures, and this leads to better surface quality and more efficient fabrication. This slicing is also robust due to the use of Morse theory based topological analysis of the underlying surfaces.

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MS11

Designing for Am: Integrating Mesh-Based Modelling Techniques with Parametric Cad

The growing use of additive manufacturing lifts many constraints on form imposed by CNC maching and injection molding, and has lead to a renewed interesting in applying triangle meshes, voxels, and implicit surfaces in real-world CAD systems. However, such systems should inter-operate with legacy B-Rep CAD solid modeling tools. I will discuss our ongoing attempt to combine these two domains,

relying on a combination of dynamic triangle meshes and variational mesh processing.

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MS11

Representation and Analysis of Additively Manufactured Parts

Mechanical properties of additively manufactured parts are directly related to manufacturing parameters such as the build orientation, tool path, and machine resolution. Therefore computational performance prediction for additive manufacturing should not be posed on nominal CAD models, but on a representation of the as-manufactured part. We discuss new representations of as-manufactured parts and a query based structural simulation that operates directly on these representations, without the interoperability bottleneck of approaches such as finite element analysis.

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MS12

C1 Assembly of Quadrilateral Patches, Some Properties Relating to their Geometry

We consider a C1 assembly of two patches with a common straight edge and a cubic spline boundary . The corresponding constraints depend strongly on the geometry and the parametric definition of the two patches. We analyze several configurations and show that a construction of basis functions is always possible for unstructured meshes with 5th order tensor Bézier patches , but may fail for 4th order one. We analyze the consequences for Spline based IGA.

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MS12

Adaptive Isogeometric Analysis on Multi Patch Domains

Isogeometric discretizations should allow for adaptive mesh refinement and guarantee optimal smoothness of the numerical solution. Multi-patch discretizations are required for more complex geometries. We present a new framework that enables us to construct bases for isogeometric spline spaces on multi-patch domains. In particular we focus on achieving higher smoothness across interfaces. The advantages of our framework will be demonstrated by numerical examples, showing potential applications of the new bases in Isogeometric Analysis.

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MS12

Iga Across Irregularities

Matched G^k constructions for geometry and analysis automatically yield C^k iso-geometric elements also for non-tensor-product layout. The talk reviews the use of such elements towards solving partial differential equations in two and three variables and on free-form surfaces.

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MS12

Spline Manifold Spaces for Isogeometric Analysis

We introduce and study a mathematical framework for analysis-suitable unstructured B-spline spaces. In this setting the parameter domain has a manifold structure, which allows for the definition of function spaces that have a tensor-product structure locally, but not globally (including multi-patch B-splines, or unstructured T-splines). Within this framework, we generalize the concept of dual-compatible B-splines. This allows us to prove the key properties needed for isogeometric analysis, such as linear independence and approximation properties.

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MS13

An Interactive Beam Structure Design Method Based on Principal Stress Lines for Additive Manufacturing

We present a novel beam structure design method based on principal stress lines (PSLs). The PSLs in a design domain with given loadings and boundary conditions are first computed. Accordingly a beam structure including its topology and shape can be interactively designed for minimum compliance. Related algorithms are given with multiple test cases. The generated structures illustrate the PSL-based beam structure design method is fast, intuitive, and has good design performance.

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MS13

Support Slimming for Single Material Based Additive Manufacturing

In layer-based additive manufacturing (AM), supporting structures need to be inserted to support the overhanging regions. The adding of supporting structures slows down the speed of fabrication and introduces artifacts onto the finished surface. We present an orientation-driven shape optimizer to slim down the supporting structures used in single material-based AM. The optimizer can be employed as a tool to help designers to optimize the original model to achieve a more self-supported shape.

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MS13

Perceptual Models of Preference in 3D Printing Direction

This work introduces a perceptual model for determining printing orientations of objects fabricated by FDM and SLA 3D printers. Our model for preference in 3D printing direction is formulated as a combination of metrics known to be important, such as area of supporting, visual saliency, preferred views and smoothness preservation. A training-and-learning methodology is developed to obtain a closed-form solution for our perceptual model. We demonstrate the performance of this method on different objects.

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MS13

Solid Mechanics Based Design and Optimization for Support Structure Generation for Additive Manufacturing

In this work, we proposed a novel design optimization method for support generation for additive manufacturing processes based on solid mechanics. Finite element analysis method is utilized to study the stress distribution on the support structure. A weighted Voronoi diagram approach is utilized to evenly distribute the support anchors. A tree stump like structure is designed for the contacting area to effectively redistribute the stress concentration. Experimental results verified the effectiveness of the proposed approach.

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MS14

LR B-Splines and Linear Independence

A sufficient condition to ensure linear indecency of LR B-splines is that no B-spline has its support nested within the support of another B-spline. However, nested supports don't necessary trigger linear dependency. The talk will look at the relations between B-splines occurring in collections of linearly dependent B-splines. Combining this with other knowledge on LR B-spline refinement will facilitate efficient algorithms guaranteeing that a collection of LR B-splines is linear independent.

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MS14

Complexity of Hierachical Refinements for Strictly Admissible Mesh Configurations

An adaptive isogeometric method based on truncated hierarchical spline constructions may be derived by considering a refine module that preserves a certain class of admissibility. It can be shown that the overlay of two strictly admissible meshes is a mesh of the same kind with bounded cardinality. In addition, the complexity of the algorithm can be derived by analysing the interplay between the number of refined elements and the total number of marked elements.

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MS14

Splines on Triangles

We consider using splines on triangulations in combination with splines on T-meshes.

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MS14

Polycube-Based Volumetric T-spline Construction

for Isogeometric Analysis

In this talk, several polycube-based schemes are described to construct trivariate solid T-splines for isogeometric analysis. For arbitrary topology objects, the polycube can be constructed using smooth harmonic scalar fields, Boolean operations, skeleton and centroidal Voronoi tessellations. A parametric mapping is then used to build a one-to-one correspondence between the input triangulation and the polycube boundary. After that, we create valid T-meshes through pillowing, quality improvement and applying templates to handle extraordinary nodes.

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MS15

Perspective in the Conformal Model and in the Standard Homogeneous Model

Abstract not available.

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MS15

Perspective in R(4,4)

Abstract not available.

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MS15

Perspective Projection in Homogeneous Models

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MS15

Introduction to Clifford Algebras and Geometries

Abstract not available.

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