IP1

Thinking Outside the CAD Box: Geometric Design in the Age of 3D Printing

For the last four decades, CAD tools have played an increasingly critical role in the product design process and in shaping our design thinking. But with the advent of 3D printing, traditional geometric modeling isnt keeping pace. While CAD systems have become faster, cheaper, and easier to use, they offer only limited access to the vast new space of geometric complexity now within our reach. This talk will outline new design and geometric representation paradigms that are emerging (and sometimes re-emerging): From generative geometry and evolutionary design, to multimaterial topological optimization and dynamical blueprints.

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IP2

Conformalizing Mean Curvature Flow Computer Science or Mathematics?

In this talk we will revisit a well-studied problem from the mathematical community the formations of singularities in the mean curvature flow of 2D surfaces. Exploring the flow from the perspective of computer science, we relate the formation of singularities to a division-by-zero in the implementation. We show that a simple algorithmic modification that removes the division-by-zero also results in a geometrically simpler flow that empirically has been shown to evolve genus zero surfaces to conformal parameterizations over the round sphere.

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IP3

FMaps - Algebraic Tools for Reasoning about Shapes and their Collections

Can you compare apples to oranges? When considering two geometric data sets (say an apple and an orange), the first question one could ask is "how similar are they", and the answer can be quantified by a single number. A more interesting question is "where do they differ?", because while both a horse and a human are different from a centaur, they are so in different ways. In this talk we will present FMaps - a new computational tool for reasoning about shapes, their differences and differences of differences. We will show how a simple change of perspective allows us to use standard linear algebra tools for complex tasks such as computing maps between shapes, analyzing and visualizing them, computing shape analogies and intrinsically aligning shape collections.

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IP4

Hierarchical Data Structures for Freeform Geometric Models

We present recent developments in the design of hierarchical data structures for freeform geometric models. The design of suitable data structures is essential in the acceleration of geometric algorithms for freeform curves and surfaces, in particular, when the freeform shapes are under continuous deformation. We demonstrate the performance improvement of various recent geometric algorithms over conventional results by orders of magnitude in computing time. We also show how the basic properties of spline functions can be used in the development of parametric data structures, their matching, and the Hausdorff distance bounding.

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IP5

Topological Methods for Data Understanding and Exploration

Scientific visualization aims to provide insights into data by generating a visual representation of the data and by providing methods for the user to interactively explore and interact with this representation. Topological methods, based on ideas from algebraic topology and Morse theory, have been successfully employed in the past decade to provide succinct and abstract representations of features in the data. One such topological structure is the Reeb graph, which is an abstract representation of the topology of all isosurfaces of a scalar field. In this talk, I will describe the role of the Reeb graph in the development of visualization methods for data from various science and engineering domains. I will focus on challenges in terms of efficient representation of the Reeb graph, fast computation, controlled simplification, and effective visualization.

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IP6

Geometry in CAD Systems: Past, Present, and Future

The internal workings of commercial CAD/CAM/CAE systems are typically something of a mystery to people outside the industry. The talk describes the evolution of geometric representations in commercial/industrial systems, in the hope that a better understanding of how we do things (and especially why we do them) will be of value to the research community. We describe the chaos of the early days, the relative calm and uniformity of today, and some likely directions for the future.

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CP0

Longest-Edge Algorithms for Size-Optimal Refinement of Triangulations

Longest-edge refinement algorithms were designed to iteratively refine the mesh for finite-element applications by maintaining the mesh quality (assuring a bound on the smallest angle). In this paper we improve geometrical results on longest-edge refinement algorithms and provide precise bounds on the refinement propagation. We prove that the iterative application of the algorithm gradually reduces the average extent of the propagation per target triangle, tending to affect only two triangles.

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CP0

Extraction of Generative Processes from B-Rep Shapes and Application to Idealization Transformations

The construction tree produced during the design process of B-Rep objects does not bring all the desired properties in many configurations: dimension modifications, idealization processes. This paper proposes a primitive-based approach to extract generative processes from a given B-rep. The resulting construction graph generates a set of additive generative processes which, in the context of finite element analyses, can efficiently improve the idealizations of extracted primitives and ensure robust connections between them.

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CP0

Implicit Matrix Representations of Rational Bzier Curves and Surfaces

We introduce and study a new implicit representation of rational Bzier curves and surfaces in the 3-dimensional space. This representation consists of a matrix whose entries depend on the space variables and whose rank drops exactly on this curve or surface. Then, we show that these implicit matrix-based representations adapt geometric problems, such as intersection problems, to the powerful tools of numerical linear algebra, as the singular value decomposition, with a good numerical stability.

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CP0

Modeling Piecewise Helix Curves from Sketches

We describe a method for reconstructing piecewise helix curve from 2D sketch. The system takes as input a polygonal curve and generates a piecewise helix curve such that its orthogonal projection matches the input curve. The first step is an algorithm to generate a set of helices such that their orthogonal projection approximates the input curve. This step is followed by a global optimization to minimize the tangent discontinuity of the junctions of the helices.

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CP0

Geometry Seam Carving

We present a novel approach to feature-aware mesh deformation that combines elastic Laplacian editing with discrete plastic deformations by transferring the concept of seam carving from image retargeting to mesh deformation. During editing, a pre-computed set of triangle strips, or geometry seams, can be deleted or inserted in low saliency mesh regions, thereby distributing the deformation distortion non-homogeneously over the model which preserves salient features much better.

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CP0

Improving Spatial Coverage While Preserving Blue Noise of Point Sets

A well-spaced blue-noise distribution of points has a random Fourier spectrum and small Voronoi cell aspect ratios. Totally random distributions have no aspect ratio bounds, and perfect tilings have no randomness. Smoothing a random input to locally optimize aspect ratios improves well-spacedness while preserving randomness. We simultaneously get good, middling values for both; better than CVT, Farthest Neighbor, and DistMesh. We show meshing and filtering applications.

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CP0

Modeling by Composition

Functional composition can be computed efficiently, robustly, and precisely over polynomials and piecewise polynomials represented in the Bezier and B-spline forms. In this work, as a testimony to the value of functional composition, we recall applications to curve-curve and curve-surface composition, and more extensively explore the surface-surface composition (SSC) in geometric modeling. We demonstrate the great potential of functional composition using several examples of the SSC operator, in geometric modeling applications.

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CP0

Computation of Components' Interfaces in Highly Complex Assemblies

This paper proposes a method to rapidly and fully automatically generate a precise geometric description of interfaces in generic B-Rep CAD models. The approach combines an efficient GPU ray-casting technique commonly used in computer graphics with a graph-based curve extraction algorithm. Not only is it able to detect a large number of interfaces efficiently, but it also provides an accurate Nurbs geometry of the interfaces, that can be stored in a plain STEP file.

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CP0

Solving Multivariate Polynomial Systems Using Hyperplane Arithmetic and Linear Programming

We present a new method for solving systems of polynomial constraints, which scales nicely for systems with a large number of variables and relatively low degree. Such systems appear in many application domains. The method is based on the concept of bounding hyperplane arithmetic, which can be viewed as a generalization of interval arithmetic. We have implemented our method and present experimental results. The method is compared to previous methods and its advantages are discussed.

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CP0

Leading a Continuation Method by Geometry for Solving Geometric Constraints

Geometric constraint problems arise in domains such as CAD, Robotics, Molecular Chemistry, whenever one expects 2D or 3D configurations of some geometric primitives fulfilling some geometric constraints. Most well-constrained 3D problems are resistant to geometric methods. They are often solved by purely numerical methods that are efficient but provide only one solution. This paper focuses on using geometric knowledges to specialize a so-called coefficient parameter continuation to 3D geometric constraint systems.

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CP0

Isogeometric Analysis on Triangulations

We present a method for isogeometric analysis on triangulation of a domain bounded by NURBS curves. Both the geometry and the physical field are represented by bivariate splines in Bernstein Bezier form over the triangulation. We describe a set of procedures to construct a parametric domain and construct Cr-smooth basis functions. This method is applicable to complex topologies and allows highly localized refinement. Isogeometric analysis of problems from linear elasticity and advection-diffusion analysis is demonstrated.

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CP0

Modeling Flow Features with User-Guided Streamline Parameterization

We present a novel approach for designing streamline-based, free-form surface features in the context of product design. The user first designs a network of streamlines on the base shape, by performing a stroke-constrained mesh parameterization. Then, the user utilizes these streamlines as a curvilinear scaffold for creating 3D features that are bounded and parameterized by them. The user applies fine-grained control of the resulting 3D features by manipulating the streamlines.

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CP0

Precise Convex Hull Computation for Freeform Models Using a Hierarchical Gauss Map and Coons Bounding Volume Hierarchy

We present an interactive-speed algorithm for computing the precise convex hull of freeform geometric models. The

algorithm is based on two pre-built data structures: a Hierarchical Gauss map and a Coons bounding volume hierarchy. We recursively build approximate convex hulls using the data structures and eliminate the majority of redundant surface patches. In the final stage, we compute the precise trimmed surface patches on the convex hull boundary using numerical methods.

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CP0

Computing Voxelized 3D Minkowski Sums on the GPU

We present an algorithm for directly computing a voxelization of the Minkowski sum of two arbitrary closed watertight input polyhedra for applications such as path planning that do not require a boundary representation as output. We introduce a new decomposition formula for computing the Minkowski sum and prove its correctness. We describe an efficient Graphics Processing Unit (GPU) implementation of the algorithm using stencil shadow volumes to create a solid voxelization of the Minkowski sum.

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CP0

Robust Cascading of Operations on Polyhedra

We present an algorithm for robustly implementing sequences of operations on polyhedra. We modify the input to each operation by rounding the output of the previous operation to floating point, randomly perturbing, and ensuring that the result represents a polyhedron. We demonstrate our algorithm on a packing algorithm with ten cascaded Minkowski sums and set operations.

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CP0

Self-Overlapping Curves: Analysis and Applications

When a 2D disk is stretched arbitrarily with possible self-overlaps, without twisting, its boundary forms a complex curve known as a self-overlapping curve. The mapping between the disk and its deformed self, also called the disk immersion, is useful in many applications like shape morphing and curve interpretation. Given a self-overlapping curve, an algorithm for computing its immersion is presented, which has an average time complexity quadratic in the number of points on the curve.

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CP0

Electromagnetic Control of Charged Particulate Spray Systems - Models for Planning the Spray-Gun Operations

This work concerns the use of externally applied electromagnetic fields in charged particulate spray systems. We present a set of simple physical and geometric arguments for identifying the mapping between spray-gun trajectory and the target surface - along with the parametric dependence of the mapping on operation parameters and the applied fields - and illustrating their role in constructing physically based process simulations. Sensitivity to process parameters is also characterized for a given applied field.

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CP0

Automated Fixture Configuration for Rapid Manufacturing Planning

Practical fixture configuration largely remains an experience driven manual activity to enable customization for varying workpiece geometry, and most automated solutions do not scale well to accommodate such variation. In this pape, we address the problem of rapidly synthesizing a realistic fixture that will guarantee stability and immobility of a specified polyhedral work-part. The paper addresses both theoretical and practical issues in 3D fixturing and makes contributions to both. Many examples are shown.

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CP0

A Unified Method for Hybrid Subdivision Surface Design Using Geometric Partial Differential Equations

This research presents a novel technique to evaluate the finite element basis functions and the first attempt for constructing GPDE subdivision surface with hybrid control meshes consisting of triangles and quadrilaterals. We choose the mean curvature flow and Willmore flow as our driven GPDEs, and the finite element method coupled with a hybrid Loop and Catmull-Clark subdivision algorithm as the numerical simulation method.

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CP0

Linear Algebraic Representation for Topological Structures

We advocate that a proper mathematical model for all topological structures is a (co)chain complex: a sequence of (co)chain spaces and (co)boundary mappings. This implies all topological structures may be represented by a collection of sparse matrices. We propose a Linear Algebraic Representation (LAR) scheme and show that it supports variety of topological computations using standard matrix algebra, without any overhead in space or running time. Full open source implementation of LAR is now available.

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CP0

Geometric Interoperability with Queries

The problem of geometric (model and system) interoperability is conceptualized as a generalization of the problem of part interchangeability in mechanical assemblies. Interoperability subsumes the problems of geometric model quality, exchange, interchangeability, and system integration. Most interoperability proposals have been data-centric. Instead, we advocate a query-centric approach that can deliver interoperable solutions to many common geometric tasks in computer aided design and manufacturing, including model acquisition and exchange, metrology, and computer aided design/analysis integration.

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CP0

Kinematic Skeleton Extraction from 3D Articulated Models

We propose a kinematic skeleton extraction method from an articulated 3D model. Our method is a hybrid approach combining the advantages of topology-based and geometry-based methods using the Morse theory and the shape descriptor. This method does not require manually-chosen feature points or markers, is independent of both postures and the number of branches in the model, and can efficiently extract kinematic skeletons that can be directly applied to the character rigging.

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CP0

GaFinC: Gaze and Finger Control Interface for 3D Model Manipulation in CAD Application

We propose an improved gesture control interface for 3D modeling manipulation tasks that possesses conventional interface level usability with low user fatigue while maintaining a high level of intuitiveness. By analyzing problems associated with previous hand gesture controls in translating, rotating and zooming, we developed a multi-modal control interface called GaFinC. GaFinC can track precise hand position and recognize several finger gestures and utilizes an independent gaze pointing interface for setting the point of interest.

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CP0

High-Quality Vertex Clustering for Surface Mesh Segmentation Using Student-t Mixture Model

In order to robustly perform segmentation for industrial objects measured by a 3-D scanning device, we propose a new method for high-quality vertex clustering on a noisy mesh. Using Student-t mixture model with the variational Bayes approximation, we develop a vertex clustering algorithm in the 9-D space composed of three kinds of principal curvature measures along with vertex position and normal component. We demonstrate effectiveness of our method by applying it to real-world scanned data.

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CP0

Puzzhull: Cavity and Protrusion Hierarchy to Fit Conformal Polygons

We present a simple definition for, and a method to find, cavities and protrusions of a 2D polygon. These geometric features are then used to find fitting polygons, as in the case of jigsaw puzzle, which in a general case is NP-hard.

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CP0

An Optimization Approach for Constructing Trivariate B-Spline Solids

We present an approach that automatically constructs a trivariate tensor-product B-spline solid via a gradient-based optimization approach. Given six boundary B-spline surfaces for a solid, this approach finds the internal control points so that the resulting trivariate B-spline solid is valid in the sense the minimal Jacobian of the solid is positive. It further minimizes a volumetric functional to improve resulting parametrization quality. Our approach employs elastic deformation, constraint aggregation, divide-and-conquer and hierarchical optimization techniques.

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CP0

How the Beast Really Moves: Cayley Analysis of Mechanism Realization Spaces Using CayMos

For a commonly occurring subclass of 1-dof tree-decomposable linkages in 2D, we give a canonical bijective representation and visualization of the connected components of the Euclidean realization space, as curves in a carefully chosen Cayley parameter space. This also allows us to find a shortest "distance" between connected components. By implementation of these results in our new software CayMos, we give new observations about the realization spaces of many well-studied 1-dof linkages including the Strandbeest.

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CP0

Geometric Computation and Optimization on Tolerance Dimensioning

An efficient geometric method of tolerance analysis is presented for optimizing dimensioning and providing an optimal processing plan for a discrete part. A topological graph is introduced to represent the geometric primitives and dependencies in dimensioning. The tolerance zone is obtained by translating parametric models into corresponding geometric computations. Geometric optimization is applied to the graph in order to find the optimal dimensioning scheme. Applications include tolerance analysis, dimension scheme optimization, and process planning.

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CP0

A Parallel Algorithm for Improving the Maximal Property of Poisson Disk Sampling

This paper presents a simple yet effective algorithm to improve an arbitrary Poisson disk sampling to reach the maximal property. Our algorithm has a natural parallel structure and is memory efficient and flexible that can generate maximal Poisson disk sampling in an arbitrary 2D polygon or 3D polyhedron. Furthermore, it can be extended from Euclidean space to curved surfaces in an intrinsic manner, which distinguishes itself from other parallel Poisson disk sampling techniques.

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CP0

Optimizing Polycube Domain Construction for Hexahedral Remeshing

Polycube mapping can provide regular and global parametric representations for general solid models. Automatically constructing effective polycube domains, however, is challenging. We present an algorithm for polycube construction and volumetric parameterization. The algorithm has three steps: pre-deformation, polycube construction and optimization, and mapping computation. Compared with existing polycube mapping methods, our algorithm can robustly generate desirable polycube domain shape and low-distortion volumetric parameterization. It can be used for automatic high-quality hexahedral mesh generation.

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CP0

A Simple and Local Method for Computing Teichmller Map on 3D Surfaces

We present a simple yet effective technique to compute Teichmller map on surfaces of non-trivial topology. Our method extends the linear Beltrami solver from the complex plane to manifold setting: it computes the local T-map on the local coordinate chart and then diffuses the map through the entire mesh. Our method is linear, local, easy to implement and has a very natural parallel structure. Furthermore it requires neither numerical solver nor the global coordinate system.

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CP0

Continuous Penetration Depth

We present a new measure for computing continuous penetration depth between two intersecting rigid objects. Our algorithm guarantees that both the penetration depth magnitude and direction are continuous with respect to the motion parameters. We have applied our algorithm to complex rigid models composed of tens or hundreds of thousands of triangles and the runtime query takes only around 0.01 milliseconds.

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CP1

Geometric Characteristics of Quadric Bézier Triangular Patches

We derive expressions for implicit equations of quadric Bézier triangular patches in terms of their control nets and weights, and also for the tangent planes to the quadric. This allows us to use control nets and weights to classify quadrics and to derive expressions for their geometric characteristics (centers, vertices, axes...)

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CP1

Aesthetic Spiral Design With Control Points

This paper elucidates the properties of Generalized Log-Aesthetic Curves (GLAC) for CAD practicalities. It is an extension of the emerging Log-Aesthetic (LA) curve with an extra DoF encompassing clothoid, circle involute, logarithmic spiral and etc. The first section analyzes the bounds of GLAC and identifies the occurrence of inflection points based on DoFs (ν, Λ and α). The second section describes the algorithm to generate GLAC interactively with three control points. The final section verifies the superiority of GLAC by depicting drawable regions of GLAC and comparing them to LA curves.

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CP1

Fair Bi-4 Surfaces

The construction fills multi-sided neighborhoods in a bi-3 spline complex. Guide surfaces and a novel splitting of G^1 constraints consistently yield fair highlight distribution, even for input with extreme curvature variation.

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CP1

Volume-Oriented Tangential Redistribution of Points on Evolving Manifolds

We present a method that can be used for improving the mesh quality of evolving discretized manifolds. The method is based on a specifically designed tangential redistribution of points during the evolution process. We formulate the results in a general continuous setting and then we demonstrate the performance of our method on the special case of mean curvature flow of surfaces in $\mathbb{R}^3$. We show how we can obtain an asymptotically uniform mesh with respect to the area of mesh elements or how we can preserve relative volumes of mesh elements during the evolution.

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CP1

Complete Log-Aesthetic Surfaces by Logarithmic Helical Sweep

We propose a new category of aesthetic surfaces, called complete log-aesthetic surfaces, all of whose isoparametric curves are log-aesthetic curves. Log-aesthetic curves are curves with linear logarithmic curvature graphs, and such linearity has been confirmed in many existing aesthetic curves. Complete log-aesthetic surfaces are generated by sweeping a log-aesthetic curve segment along a logarithmic helix, a special case of log-aesthetic space curves. Some features of the surfaces, such as Gaussian curvature, are presented.

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CP1

Selective Degree Elevation for Multi-Sided Bezier Patches

This work presents a method to selectively elevate the degree of multi-sided Bézier patches of arbitrary dimension over any domain without self-intersections. Users selectively insert control points of higher degree while maintaining the polynomial reproduction order of the original patch. This elevates the degree of desired portions of the patch adding degrees of freedom and maintaining continuity with adjacent patches without elevating the degree of the entire patch, avoiding creation of unnecessary degrees of freedom.

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CP2

Modeling of Countercurrent Two-Phase Interacting Flows: A Geometric Approach

A number of chemical engineering unit operations involve two-phase countercurrent flows brought into contact. Mathematically, this type of system can be representated by a hyperbolic conservation law with two dependent variables. If the equilibrium between the two phases is attained instantaneously, a constraint equation must also be considered. Furthermore, if a chemical reaction occurs in one of the phases, the conservation law becomes inhomogeneous. The paper will focus on construction and classificaton of the steady-state solutions that may occur depending on the geometry of the constraint curve, which is frequently not convex (usual assumption in analysis of conservation laws).

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CP2

On-Line Reconstruction of 3d Geometry

In reverse engineering and computer-aided design (CAD) applications point cloud data is usually manually acquired, reconstructed, and post-processed in separated steps. The operator of a hand-held laser scanner has no feedback from the reconstruction results. On-line reconstruction of 3d geometry allows for such an immediate feedback. Regions where the scanned data is insufficient for the reconstruction can be detected on the fly to allow an immediate correction. This enables the operator to focus on critical regions in the scanned data to improve the reconstruction quality. This talk focuses on on-line segmentation and reconstruction of basic geometric primitives. The presented methods allow for an interactive processing of a point stream. These methods feature data structures that can be updated at any time if additional data from the stream has to be processed. This data is used to complete and improve the segmentation and reconstruction during the scanning process.

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CP2

Uniformly Triangulated Minimal Surfaces in Architecture

We present novel method for finding minimal surfaces with application in design of triangular shell structures in architecture. Our method is based on mean cutvature flow of initial triangulated surface with boundary to a minimal surface. The flow of the surface in normal direction is accompanied by an originally designed tangential redistribution of points on evolving surface which causes uniform discretization of selected curves forming the surface triangulation.

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CP2

Physical Models and Simulation in Procedural Modeling

Models of hydraulic erosion have to account for the dynamic conditions present in a variety of physical systems. However, synthesis of erosion features by simulation suggests a way of reducing the diversity of the underlying models by emphasizing principles of self-organization, such as emergent behavior and avalanching. For a concrete illustration, I will discuss the role of self-organization in the development of several models of erosion with applications in terrain generation.

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CP2

Earthquake Modeling with Lévy Processes

A new earthquake model using a Levy driven stochastic processes will be discussed. Assuming variance of the process is an Ornstein-Uhlenbeck type process this will lead to the Barndorff-Nielsen and Shephard (BN-S) model for earthquake data. Improvement over the previous related results will be discussed. This model has potential geoscientific applications in estimating earthquakes in certain regions.

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CP2

Adaptive Vehicle Make Design Performance Verification through Physics-based Simulation

DARPAs Adaptive Vehicle Make (AVM) program is developing extensive design, analysis, and production software and is building a production line to support the goal of greatly reducing vehicle development time (see VehicleForge.org). We describe how the conceptual through detailed designs are analyzed to confirm performance to achieve correct by construction. This includes automatic meshing of CAD geometries for physics-based simulations. The first vehicle that rolls off the production line is intended to be fully operational.

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CP3

Adaptive Meshes for Realistic Tokamaks Geometries Using IsoGeometric Analysis

Designing realistic and exact geometries for actual tokamaks is an important step for studying and understanding non-linear MHD and kinetic models. We are interested in adaptive meshes as part of an r-adaptive strategy for solving partial differential equations with evolving internal structure, such as those encountered in non-linear MHD and Kinetic models. In particular, flux aligned meshes are used for the equilibrium state, while equidistributed meshes are used for high anisotropic diffusion problems, ELMs simulations and strong turbulence.

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CP3

Shape Design and Isogeometric Analysis over An Arbitrary Parametrization Using Mapped Basis Functions

This talk presents a novel method for shape design and isogeometric analysis from a quadrilateral control mesh of arbitrary topology using mapped basis functions. Based on an arbitrary input quadrilateral control mesh, a global parametrization of the final surface is first defined through a Gravity Center Method (GCM). A re-parametrization method is then applied to map a given basis function to others tailored to each of the control vertices which can be either regular or extraordinary ones. The final surface is defined by all the input control vertices with their corresponding mapped basis functions patch by patch. Depending on the continuity of the original basis function used for mapping to others, the global continuity of the resulting surface, including at extraordinary positions, can be of an arbitrarily higher order. In this talk, a uniform cubic B-spline basis function is used to illustrate the method and the resulting surface is globally C^2 continuous. Several examples are provided to demonstrate the proposed method for both shape design and isogeometric analysis. Other basis functions can also be used for mapping purpose and the method can also be extended to non-quadrilateral control meshes.

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CP3

Hierarchies Generated by Nested Generating Systems

In order to provide the possibility of local refinement, several generalizations of tensor-product splines have been explored, such as hierarchical splines. We consider a generalized hierarchical spline space which is based on a nested sequence of (possibly linearly dependent) generating systems, such as box-splines. We analyze the properties of the space obtained by collecting functions with respect to a decreasing sequence of hierarchical domains and explore applications in geometric design and isogeometric analysis.

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CP4

Parameterization-Aware Mip-Mapping

We present a method of generating mipmaps that takes into account the distortions due to the parameterization of a surface. Our method downsamples warped textures by assigning texels weights proportional to their area on a surface and filters textures for best reproduction by the postfilter used on the GPU. Our method improves texture filtering but only modifies mipmap generation, requires no modification of art assets or rasterization algorithms, and does not affect run-time performance.

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CP4

Topologically Informed, Geometrically Robust Molecular Visualization

Synchronous dynamic visualizations of bio-molecular simulations are crucial 0-th order analyses for the Big Data generated. Reliable visualization depends upon topological guarantees so that domain scientists do not draw unwarranted inferences. Responsive numerical techniques on the underlying spline models, inclusive of rigorous error bounds, are presented for high performance computing environments.

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CP4

Using Adaptive Composite B-Spline Grid Generation to Enhance 3D Web Visualizations

We describe an adaptive grid generation technique based on the composition of tensor product B-spline mappings, $\mathbf{T}$ and $\mathbf{\Phi}$, where $\mathbf{\Phi}$ maps the unit square onto itself and $\mathbf{T}$ maps the unit square onto the desired physical domain. Variational methods are used to adjust the $\mathbf{T}$ and $\mathbf{\Phi}$ coefficients to move grid points without disturbing the accuracy of the boundary approximation. The effectiveness of the method on both convex and nonconvex domains is demonstrated. Applications to the development of computational grids for the rendering of complex mathematical function surfaces on the web are shown.

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CP5

Nonlinear Diffusion Filtering of Data on the Earth's Surface

We present data filtering based on a numerical solution of linear and nonlinear diffusion equations on closed surfaces, namely on the Earth's surface. The Earth is approximated by a polyhedral surface created by planar triangles and we construct a dual co-volume grid. On the co-volumes we define a weak formulation of the problem by applying Green's theorem to the Laplace-Beltrami operator. Then we introduce a surface finite-volume method to discretize the weak formulation. In case of nonlinear diffusion we use the regularized surface Perona-Malik model. In our numerical experiments we reduce noise from the GOCE satellite mission observations and from the mean dynamic topography over oceans.

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CP5

Mesh Denoising Via L0 Minimization

We present an algorithm for denoising triangulated models based on L0 minimization. Our method maximizes the flat regions of the model and gradually removes noise while preserving sharp features. As part of this process, we build a discrete differential operator for arbitrary triangle meshes that is robust with respect to degenerate triangulations. We compare our method versus other anisotropic denoising algorithms and demonstrate that our method is more robust and produces good results even in the presence of high noise.

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CP5

Laplace Inversion of Lr-Nmr Relaxometry Data Using Sparse Representation Methods

LR-NMR relaxometry is a powerful tool that can be harnessed for characterizing constituents in complex materials. Conversion of the relaxation signal into a continuous distribution of relaxation components is an ill-posed problem. We provide a numerical optimization method for analyzing LR-NMR data by including L1 regularization and applying a convex optimization solver PDCO. Our integrated approach includes validation of analyses by simulations, testing repeatability of experiments, and validation of the model and its statistical assumptions. The proposed method provides better resolved and more accurate solutions compared to those suggested by existing tools.

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CP5

Balloon Darts: Fast Approximate Union Volume in High Dimensions with Line Samples

We approximate the volume of the union of d-dimensional balls. Deterministic, exact approaches are too slow for high dimensions. We adapt these to sampling balls with randomly-oriented lines through their centers: pop balloons by spoke darts. We compare the efficiency to Monte Carlo and Bringmann and Friedrich's point-sampling methods. A line sample works well because it gives more information than a point sample and is almost as fast.

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CP5

Adaptively Weighted Numerical Integration over

Arbitrary Domains

For a given set of quadrature points and order of integration, the weights are obtained by solving a system of suitable moment equations in least square sense. The computed weights adapt to the geometry of the domain allowing accurate integration over variety of non-traditional, imprecise, or non-conforming representations without excessive subdivision, which is useful in many applications including meshfree analysis. Experimental results indicate that adaptively weighted integration compares favorably with more traditional domain decomposition approaches.

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MS1

Trends in Geometric Representations

For the past 20 years or so, there has been little change in the set of techniques used to represent geometry in commercial CAD/CAM/CAE systems. However, some new approaches are being stimulated by hardware changes and by convergence with the game/entertainment industries. This talk examines some possible changes and their consequences.

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MS1

New Challenges in Isogeometric Analysis

Numerous papers illustrate the superiority of Isogeometric Analysis (IgA) compared to traditional Finite Element Analysis for many problems. However, so far the use of IgA in industry is limited. We will address different causes for this slow uptake of IgA in industry, and address possible actions and activities needed for speeding up the uptake of IgA.

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MS1

Geometric Modeling with Convolutions

Modern engineering design with laminated, composite materials makes challenging demands of geometric modeling and processing systems, and complex products such as the Boeing 787 add to the difficulty. While a complete solution to these challenges is still many years away, progress has been made addressing some of the issues. One promising technique has been applying convolution operators to build high quality geometry models. Early experiments suggest that many interesting and powerful convolution-based geometric constructions are possible.

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MS1

Challenges in Geospatial Applications

The talk will present challenges in handling and visualizing the information hidden in large heterogeneous geospatial data sets. It is based on the work in the on-going European project “IQmulus: a high-volume fusion and analysis platform for geospatial point clouds, coverages and volumetric data sets”. This four-year project addresses the definition, configuration and deployment of functional spatial processing services for test cases in marine spatial planning and land applications for rapid responses and territorial management.

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MS2

Challenges in Simulation based Engineering

Simulations have become an essential part in the engineering process. Currently many different simulation models are used to ensure the desired characteristics of an object (product or production site) on virtual prototypes. The increase in computing power and new technologies allows to advance the separated model islands towards a digital twin that accompanies the whole lifecycle of the object. In this talk the challenges and profits of the digital twin are discussed from an industry point of view.

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MS2

Challenges for Geometric Design

Abstract not available at time of publication.

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MS2

Challenges in the Building Industry

The construction of advanced architectural designs is presently a very labour intensive and costly process. It is therefore limited to a few prestige projects and it is a major challenge to the building industry to bring the cost down and thereby offer architects more variability in the economically feasible designs – allow them to think out of the box. To address this challenge “The Danish National Advanced Technology Foundation’ has supported the “BladeRunner’ project that involves several Danish companies and public institutions. It aims to reduce the amount of manual labor by applying robots to cut EPS-moulds for concrete using the Hot Wire or Hot Blade technology. The mathematical challenge is to rationalise the architects’ CAD drawings into surfaces that can be created by these technologies.

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MS2

Efficient Geometry: Compositions and a Good Parametrization

My crystal ball has me anxious for two advances in geometric modeling: effective use of compositions of functions and practical algorithms for “good” geometry parametrization. The intersection of a surface and a curve on a surface is a geometric object given by function composition–the curve is a function into the parameter space of the surface. Finding the intersection means solving a system of equations involving compositions, which has not been widely investigated. Geometry parametrizations, on the other hand, have been extensively studied (cf., e.g., FloaterHormann2005). This and similar capabilities have many uses in geometry for manufacturing. But it is still difficult to make effective use of the existing methods.

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MS3

LR B-splines

Starting from a tensor product B-spline basis collections of LR B-splines and a corresponding LR-mesh are generated in a sequence of successive local refinements. Such refinements must split the support of at least one B-spline. The approach applies equally well in higher dimensions. To check for linear independence the ”peeling algorithm” can be used, or alternatively each refinement must be ”hand-in-hand” and generating just the number of B-splines necessary to span the spline space.

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MS3

Hierarchical T-Splines

Hierarchical B-splines were originally introduced in the CAD community nearly thirty years ago. Currently, hierarchical spline techniques are restricted to tensor product B-splines and NURBS. This restriction, coupled with the difficulty of encoding geometric information in the hierarchy, has greatly hampered their adoption as a CAD tool. To overcome these limitations we have extended analysis-suitable T-splines to the hierarchical unstructured regime. In this way, the design advantages of T-splines can be leveraged while introducing the analysis advantages of easily controlled hierarchies of locally refined analysis-suitable T-spline spaces. We present a simple characterization and construction for hierarchical analysis-suitable T-splines and demonstrate their potential as a basis for adaptive isogeometric analysis.

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MS3

LR B-Splines and Adaptive Refinement in Fluid Mechanics

Locally Refinable (LR) B-splines represent a novel approach to local refinement within isogeometric analysis. In this work we present numerical investigations of the use of LR B-splines for isogeometric analysis of flow problems. The problems considered are governed by the steady-state, incompressible Navier-Stokes equations in two dimensions. We propose a set of LR B-spline discretizations of the velocity and pressure fields, and we investigate their stability and convergence properties through representative examples.

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MS3

Isogeometric Spline Forests

In this talk we present isogeometric spline forests. An isogeometric spline forest is a hierarchical spline representation posed over a surface or volume of arbitrarily complex geometry and topological genus. Spline forests can accomodate arbitrary degree and smoothness in the underlying hierarchical basis as well as non-uniform knot interval configurations. We describe adaptive h-refinement and coarsening algorithms for isogeometric spline forests and demonstrate their potential in the context of several demanding analysis problems.

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MS4

Curve Topology Certification Problems Arising in Geodesy: Transforming 3D Cartesian Coordinates To Geodetic Coordinates

Closed form solutions for transforming 3D Cartesian to geodetic coordinates reduce the problem to finding the real solutions of the fourth degree latitude equation or variations of it. By using curve topology certification techniques for algebraic curves defined implicitely we characterize completely the region where Vermeille’s approach, the most popular analytical method dealing with this problem, can not be applied. Moreover we introduce a new method for solving the latitude equation for those cases not covered by Vermeille's approach.

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MS4

Algebraic and Analysic Results for Truncated Hierarchical B-Splines

The interest in hierarchical techniques for tensor-product splines has increased recently due to the need for adaptive refinement in numerical simulation via isogeometric analysis. The newly introduced truncated hierarchical B-spline (THB) basis of hierarchical splines possesses several advantageous properties, such as partition of unity, increased sparsity and improved stability. The talk will report recent results concerning completeness, stability, approximation power and implementation aspects of THB splines.

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MS4

Collision-Detection and Distance-Related Computations for Freeform Geometric Models

Abstract not available at time of publication.

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MS4

Free-Form Shape Modeling with Cyclides Splines

We discuss how to model free-form shapes using fair and smooth cyclide splines, which are composed of Dupin cyclide patches possibly with T-joints and singularities. We overcome the inflexibility of cyclide patches by relaxing their corner vertices in a constrained optimization framework. We show test results in surface fitting and shape modeling, thus presenting the cyclide spline as a practical free-form surface representation with the exact offset property.

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MS5

From Design to Production: The TERRIFIC Demonstrator Part

The TERRIFIC project covers the whole process from early design over numerical simulation towards manufacturing. Using the TERRIFIC Demonstrator Part it will be shown how isogeometry contributes during these phases of the design and manufacturing process. This includes general methods and guidelines for the design of isogeometrical friendly geometries and their segmentation into topological volumes as basis for the trivariate spline volume generation and isogeometric analysis. Having done the analysis, the machining of the part is supported, utilizing isogeometric techniques for better control and efficiency in the machining process.

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MS5

Parametrization for Eigenvalue Problems in Isogeometric Analysis

In this talk, comprehensive schemes are described to construct rational trivariate solid T-splines from boundary triangulations. For arbitrary topology objects, we first compute a smooth harmonic scalar field defined over the mesh and saddle points are extracted to determine the topology. By dealing with the saddle points, a polycube whose topology is equivalent to the input geometry is built and it serves as the parametric domain for the trivariate T-spline. A polycube mapping is then used to build a one-to-one correspondence between the input triangulation and the polycube boundary. After that, we choose the deformed octree subdivision of the polycube as the initial T-mesh, and make it valid through pillowing, quality improvement and applying templates to handle extraordinary nodes and partial extraordinary nodes. The obtained T-spline is C2-continuous everywhere over the boundary surface except for the local region surrounding polycube corner nodes.

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MS5

Advances of the Meccano Method for Isogeometric Analysis of Irregular Planar Domains

We present advances of the meccano method for T-spline modelling and analysis of complex geometries. We consider a planar domain composed by several irregular subdomains. These sub-regions are defined by their boundaries and can represent holes or different materials. The bivariate T-spline representation of the whole physical domain is constructed from a square. In this procedure, a T-mesh optimization method is crucial. We show results of an elliptic problem by using a quadtree local T-mesh refinement technique.

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MS5

Volumetric Isogeometric Descriptions Or Isogeometric Modeling of Complex Geometries

In this talk, comprehensive schemes are described to construct rational trivariate solid T-splines from boundary triangulations. For arbitrary topology objects, we first compute a smooth harmonic scalar field defined over the mesh and saddle points are extracted to determine the topology. By dealing with the saddle points, a polycube whose topology is equivalent to the input geometry is built and it serves as the parametric domain for the trivariate T-spline. A polycube mapping is then used to build a one-to-one correspondence between the input triangulation and the polycube boundary. After that, we choose the deformed octree subdivision of the polycube as the initial T-mesh, and make it valid through pillowing, quality improvement and applying templates to handle extraordinary nodes and partial extraordinary nodes. The obtained T-spline is $C2$-continuous everywhere over the boundary surface except for the local region surrounding polycube corner nodes.

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MS6

Planar Shape Interpolation with Bounded Distortion

Planar shape interpolation is widely used in computer graphics applications. Despite a wealth of interpolation methods, there is currently no approach that produces shapes with a bounded amount of distortion with respect to the input. As a result, existing interpolation methods may produce shapes that are significantly different than the input and can suffer from fold-overs and other visual artifacts, making them less useful in many practical scenarios. We introduce a novel shape interpolation scheme designed specifically to produce results with a bounded amount of conformal (angular) distortion. Our method is based on an elegant continuous mathematical formulation and provides several appealing properties such as existence and uniqueness of the solution as well as smoothness in space and time domains. We further present a discretization and an efficient practical algorithm to compute the interpolant and demonstrate its usability and good convergence behavior on a wide variety of input shapes. The method is simple to implement and understand. We compare our method to state-of-the-art interpolation methods and demonstrate its superiority in various cases.

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MS6

Locally Injective Mappings

Mappings and deformations are ubiquitous in geometry processing, shape modeling, and animation. Numerous deformation energies have been proposed to tackle problems like mesh parameterization and volumetric deformations. We present an algorithm that modifies any deformation energy to guarantee a locally injective mapping, i.e., without inverted elements. Our formulation can be used to compute continuous planar or volumetric piecewise-linear maps and it uses a barrier term to prevent inverted elements. Differently from previous methods, we carefully design both the barrier term and the associated numerical techniques to be able to provide immediate feedback to the user, enabling interactive manipulation of inversion-free mappings. Stress tests show that our method robustly handles extreme deformations where previous techniques converge very slowly or even fail. We demonstrate that enforcing local injectivity increases fidelity of the results in applications such as shape deformation and parameterization.

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MS6

Hierarchical Deformation of Locally Rigid Meshes

We propose a method for calculating deformations of models by deforming a low-resolution mesh and adding details while ensuring that the details we add satisfy a set of constraints. Our method builds a low-resolution representation of a mesh by using edge collapses and performs an as-rigid-as-possible deformation on the simplified mesh. We then add back details by reversing edge-collapses so that the shape of the mesh is locally preserved. While adding details, we deform the mesh to match the predicted positions of constraints so that constraints on the full-resolution mesh are met. Our method operates on meshes with arbitrary triangulations, satisfies constraints over the full-resolution mesh, and converges quickly.

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MS6

Bijective Composite Mean Value Mapping

We introduce the novel concept of composite barycentric mappings and give theoretical conditions under which they are guaranteed to be bijective. We then focus on mean value mappings and derive a simple procedure for computing their Jacobians, leading to an efficient GPU-assisted implementation for interactively designing composite mean value mappings which are bijective up to pixel resolution. We provide a number of examples of 2D image deformation and an example of 3D shape deformation based on a natural extension of the concept to spatial mappings.

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MS7

Isogeometric Analysis with Discontinuous Garlerkin Method

We discuss solving numerical PDEs with discontinuous Garlerkin(DG) method. The domain is represented by NURBS patches, and Isogeometric Analysis approach is proposed to solve the PDEs. Stability and convergence analysis are performed. Examples are provided to illustrate the convergence of the method.

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MS7

Conservation of Geometry and Physics in Numerical Modeling of Incompressible Flow

The incompressible Navier-Stokes equations are infused with important physical structure, evidenced by an array of balance laws for momentum, energy, enstrophy, and helicity. In this talk, I will discuss a class of spline-based discretizations that automatically replicate this structure and, through the isogeometric concept, extend to arbitrary NURBS and T-spline mapped geometries. Numerical examples illustrating the promise of this new technology will be presented.

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MS7

Spline Spaces over Rectangle Meshes with Complex Topologies

We present a new type of spline functions defined over a rectangular mesh equipped with an equivalence relation, in such a way that physical spaces with a complex topology can be represented as an homomorphic image of such meshes. We provide general definitions, a dimension formula for a subclass of these spline spaces, an explicit construction of their bases and also a process for local refinement. These developments, motivated by plane curvilinear mesh constructions are illustrated on several parametrization problems. Our main target in these constructions is to approximate isobaric lines of magnetic fields encountered in MHD simulation for Tokamaks. Their particularity is that one of the isobaric curve has a node singularity.

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MS7

Spline Forests for Discrete Differential Forms

We discuss our initial results for the construction of sequences of discrete differential forms from a forest of spline trees. Forests of spline trees allow arbitrary topologies to be represented by hierarchical splines while the discrete differential forms preserve the underlying geometric structure. This approach combines exact representation of geometry with a structure preserving basis that permit local h-refinement. Requirements for compatible forests and structure-preserving hierarchical h-refinement are also considered. The integration of these features with Bezier extraction is presented and the results are applied to benchmark problems.

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MS8

Extended Graph Rotation Systems and Its Applications to Modeling 2-Manifolds, Woven Surfaces and 3-Manifolds

In this talk, I will start to demonstrate extended graph rotation systems using rectangular paper strips that correspond to 2D thickened edges of a 2-manifold mesh. I will show how insert edge operation change the topology of orientable surfaces. I will also how edge twist operation creates non-orientable surfaces. My next demonstration will be in forming knots in 3-space by finger-traversing the boundary of the faces of non-orientables. I will show some of the results we have achieved in recent years using this basic concept. I will then demonstrate that this approach has a potential to describe 3-manifolds that can help our understanding and modeling 3-manifold structures. I expect that such a generalized 3-manifold mesh representations can be used in modeling solids, architectural shapes, high-genus surfaces, knots and links. For 3-manifolds, I will start with prisms that represents 3D thickened edges of 3-manifold meshes and discuss what kind of models can be constructed using those prisms. I will introduce the concepts of chambers and blocks. Using boundary walk I will demonstrate the faces of 3-manifolds can be both one and two-sided. If we want duality, this suggests that 3D thickened edges should also be one or two-sided and 3D thickened vertex boundaries can be any 2-manifold.

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MS8

Symmetric Surfaces and Tilings

Abstract not available at time of publication.

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MS8

Shape Optimization for Human-Centric Products with Standardized Components

In this talk, we present an optimization framework for automating the customization of human-centric products, which can be mounted on or embedded in human body (such as exoskeletal devices and implants). Such products need to be customized to fit the body shapes of users. At present, the procedure of customization is taken in an interactive manner that is inefficient. We investigate a method to automate the procedure of customization. The major difficulty in solving this problem is that we cannot freely vary the shape of every component. Many of them should be selected from the serialized standard components. Different from the existing approaches that need to fabricate all components by customized production, we develop a new method to generate customized products by using as-many-as-possible standardized components. Our work is based on a mixed-integer shape optimization framework for design automation with standardized components.

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MS8

Modeling Cmc Surfaces with Cvt

Abstract not available at time of publication.

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MS9

Verification of Mechanical Engineering Finite Element Analysis

The objective is to obtain a posteriori estimate of the discretization error of a reference problem solved using the finite element analysis. Different techniques are presented. The proposed method is particularly suited to industrial common situations. It can be used in the case where some data may be missing and can be applied to very large problem within a accessible CPU time.

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MS9

Exploiting Components Interfaces and Functional Information to Generate FE Models of Assemblies

Using the geometric interfaces information (contacts, interferences, clearances) extracted from the relative 3D location of assembly components, this approach describes how functional information can be derived and tightly linked to an assembly model. This representation is then used to identify repetitive configurations and transform adequately an assembly for FE analysis. Idealization is one of the key transformations which is addressed through a new and robust modeling trees of volume objects specifically derived for this transformation.

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MS9

From CAD to 3-Variate Spline Representation: The Terrific-Part

The creation of 3-variate spline models suited for IgA is a major game stopper when trying to introduce IgA in industry. This process is illustrated starting from a CAD-representation of the TERRIFIC demo part: IGA suitable models are created in a process including changing the surface patch structure, 3-variate block structuring, reparametrization and possibly approximation of block boundary surfaces, and the final creation of 3-variate watertight spline modes.

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PP1

Geometrical-Computational Inverse Methods for Optimal Geometrical Deformation of Lumbar Artificial Disks Using the Numerical Reuleaux Method

Lumbar artificial implants and disks experience material deformations during the rather big biomechanical loads that are acting on the lumbar spine, e.g., flexion or extension. During this biomechanical process the disks move around an Instantaneous Rotation Center (IRC), which is related to the bending moment of the implant and other physical-geometrical variables. By using the inverse geometrical algorithms of the Numerical Reuleaux Method, it is possible to select the desirable IRC and link it to the material contact mechanics and geometrical-variation parameters such as stress and strain. We present the geometrical/computational analysis of this group of formulation and carry out mathematical simulations and examples for sharp understanding.

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PP1

Finite Element Geometric Modeling of Traumatic Brain Injury for the Inverse Localization of Electrical Brain Activity Recorded Using Electroencephalography

The combined use of CT, MRI and EEG is demonstrated to (1) perform geometric modeling of the human head via the finite element method (FEM), (2) implement inverse localization of electrical activity recorded from severe traumatic brain injury (TBI) patients, and (3) inversely localize cortical generators responsible for epileptiform discharges. Ignoring pathology-related conductivity changes is found to cause substantial inaccuracies in inverse localization. Insight provided by this framework can play a beneficial role in patient recovery.

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PP1

Redevelopment of Coastline Model for Procedural Modeling

An abstract view of coastline erosion permits modeling it as a sequence of discrete events occurring at the land-ocean interface. Furthermore, the system's dynamic behavior, as proposed by Sapoval, can be described with a relationship between the coast's length and the erosion force. However, simulations of the conceptual model differ, particularly in how they calculate the coast's perimeter. After implementing several simulations, I describe a re-definition of the underlying model for procedural modeling applications.

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PP1

Bladerunner: Surface Rationalisation for HotWire and HotBlade Technology

On a small scale, Milling and 3D-printing are used in producing prototypes of geometric objects. For fast large-scale production, the HotWire and HotBlade technologies could instead produce building elements by cutting out moulds for concrete. The standard use of B-spline based CAD systems then entails the need for rationalization. Thus, a spline surface has to be segmented and each piece approximated by a surface that can be produced by the HotWire and HotBlade.

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PP1

C^2 Quasi Arc-length Polynomial Approximation to Curves

Transcendental curves, or those resulting from offsetting, are not rational and must be hence approximated to incorporate them into commercial systems. We present a systematic polynomial approximation, based on piecewise Hermite interpolation with C^2 quasi arc-length parameterization, a desirable property for robotics or CNC. We consider two alternatives (piecewise Bzier quintics and cubic B-splines), whose control points turn out to display very simple geometry. Finally, we compare our results with those from existing methods.

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PP1

Protrusion Recognition from Solid Models Using Orthogonal Bounding Factor

When a loop of concave edges is an inner loop on a single face, it is a strong hint of existence of protrusion feature and recognition of the protrusion face is straightforward. However, when a protrusion feature lies on multiple faces, it is bounded by a loop of concave edges that are not on a single face. In such cases, the rule of inner loop is no more available and recognition of protrusion faces becomes unclear. In order to address this problem, a new quantitative measure, named Orthogonal Bounding Factor (OBF), is introduced in this paper. Mathematically, OBF is defined as the sum of cross products of two consecutive vectors normal to a set of faces, and it physically represents the possibility of being a protrusion in a solid model. The formal definition of orthogonal bounding factor is established and a method to recognize protrusion features using OBF is presented.

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