CMA Centre of Mathematics for Applications

UNIVERSITETET I OSLO
DEPARTMENT OF INFORMATICS

PROGRAMME and ABSTRACTS

SEVENTH INTERNATIONAL CONFERENCE ON

MATHEMATICAL METHODS for CURVES and SURFACES

TØNSBERG, NORWAY, JUNE 26 – JULY 1, 2008

Invited Speakers

Jean-Daniel Boissonnat
Sophia Antipolis, France

Massimo Fornasier
Linz, Austria

Tom Hughes
Austin, USA

Jorg Peters
Gainesville, USA

Ragni Piene
Oslo, Norway

Robert Schaback
Göttingen, Germany

Peter Schroeder
Caltech, USA

Jonathan Shewchuk
Berkeley, USA

Joachim Weickert
Saarland, Germany

Mini-symposia Organisers

Oleg Davydov
Glasgow, UK

Tor Dokken
Oslo, Norway

Bin Han
Edmonton, Canada

Chuck Hansen
Salt Lake City, USA

Rimvydas Krasauskas
Vilnius Lithuania

Trond Kvamsdal
Trondheim, Norway

Carla Manni
Rome, Italy

Organisers

Morten Dæhlen
University of Oslo, Norway

Michael Floater
University of Oslo, Norway

Tom Lyche
University of Oslo, Norway

Jean Louis Merrien
INSA, Rennes, France

Knut Mørken
University of Oslo, Norway

Larry Schumaker
Vanderbilt University, USA

Contents

Foreword

Welcome to the Seventh International Conference on Mathematical Methods for Curves and Surfaces. The previous conferences were held in Oslo (1988), Biri (1991), Ulvik (1994), Lillehammer (1997), Oslo (2000), and Tromsø (2004). This time we gather in Tønsberg, the centre of a popular summer resort area and Norway's oldest city, dating back to early Viking times. This conference series is integrated with the French conferences (Curves and Surfaces) organised by SMAI-Association Francaise d'Approximation, and the next conference will be in Avignon, France in 2010.

With more than 170 participants and almost 140 talks, including 9 invited speakers and 7 mini-symposia, the week is going to be very busy, with a varied and interesting scientific program. We have attempted to group related talks together, but please note that there has been some late rescheduling that may have caused seemingly unrelated talks to end up together.

The conference proceedings will be published in an international journal. Details about submission of manuscripts will be announced during the conference, and on `www.ifi.uio.no/˜cagd/` after the conference.

As usual, we have had considerable help from a number of people. Andrew McMurry has helped with web programming, scripts and other technical challenges. Anne Cathrine and Nina Modahl have provided expert help with all financial issues, and Sara Mørken will assist us with registration in Tønsberg. Thank you very much to all of you!

We are grateful for financial support from the Department of Informatics and the Centre of Mathematics for Applications at the University of Oslo, and from the eVITA Program in the Research Council of Norway

Last, but not least, we thank you, the participants, for your contributions—without you, there simply would be no conference. Enjoy your time in Tønsberg!

The organisers

Scientific Programme

Time	Wed	Thu	Fri	Sat	Sun	Mon	Tue
7:30		Registration					
8:15		Opening					
8.30		Invited Talk	Invited Talk	Invited Talk		Invited Talk	Invited Talk
9.20		Coffee	Coffee	Coffee		Coffee	Coffee
9.50		Talks 4x2	Talks 4x2	Talks 4x2		Talks 4x2	Talks 4x2
11.10		Break	Break	Break		Break	Break
11.20		Talks 3x2	Talks 3x2	Talks 3x2		Talks 3x2	Talks 4x2
12.20		Lunch	Lunch	Lunch		Lunch	
12.40							The End
14:00					Excursion		
14.10		Talks 3x2	Talks 3x2	Talks 3x2		Talks 3x2	
15.10		Break	Break	Break		Break	
15.20		Invited Talk	Invited Talk	Invited Talk		Invited Talk	
16.10		Coffee	Coffee	Coffee		Coffee	
16.30		Mini-symposia Talks 4x2	Mini-symposia Talks 4x2	Mini-symposia Talks 4x2		Mini-symposia Talks 4x2	
17:00	Registration						
18.30		Talks End	Talks End	Talks End		Talks End	
19:30		Welcome Party					

For lunch and dinner we recommend that you sample the many restaurants in Tønsberg. The welcome party on Thursday night and the excursion on Sunday include dinner.

Thursday 26. June, Morning Session

Time	Room I	Room II
7.30	Registration	
	Chair: Tom Lyche	
8:15	Opening	
8.30	Invited Talk: Sampling and Stability *Robert Schaback*	
9.20	Coffee	
	Chair: Robert Schaback	*Chair: Gudrun Albrecht*
9.50	Hermite Mean Value Interpolation in $\mathbb{R}^n$ *Solveig Bruvoll*	Progressive iteration approximation property *Jorge Delgado*
10.10	Pointwise radial minimization: Hermite interpolation on arbitrary domains *Christian Schulz*	A generalized B-spline matrix form of spline *Arne Lakså*
10.30	CSG operations of arbitrary primitives with inclusion arithmetic and real-time ray tracing *Younis Hijazi*	Circular spline approximation *Xinghua Song*
10.50	Ray Casting Algebraic Surfaces using the Frustum Form *Martin Reimers*	Application of the dual Bernstein basis polynomials to the multi-degree reduction of Bézier curves with constraints *Pawel Wozny*
11.10	Break	
	Chair: Dianne Hansford	*Chair: Rick Beatson*
11.20	Computing envelope approximations using MOS surfaces *Bohumír Bastl*	Error bounds for anisotropic RBF interpolation *Oleg Davydov*
11.40	Spatial polynomial curves with different Pythagorean structures and associated frames *Carlotta Giannelli*	Biharmonic Spline Approximation from Simple Layer Potentials *Thomas Hangelbroek*
12.00	Computing with implicit support function representation of hypersurfaces *Miroslav Lávička*	An iterative algorithm with joint sparsity constraints for magnetic tomography *Francesca Pitolli*
12.20	Lunch	

Thursday 26. June, Afternoon Session

Time	Room I	Room II
	Chair: Costanza Conti	*Chair: Juan Manuel Pena*
14.10	Interpolation by Planar Cubic G^2 Pythagorean-hodograph Spline Curves *Gašper Jaklič*	A Newton Basis for Kernel Spaces *Stefan Mueller*
14.30	Hermite and Lagrangue Interpolation by Pythagorean Hodograph Curves *Zbyněk Šír*	Sharp Estimates of the Constants of Equivalence between Integral Moduli of Smoothness and K-Functionals in the Multivariate Case *Ilya V. Kachkovskiy*
14.50	Geometric Lagrange Interpolation by Planar Cubic Pythagorean-hodograph Curves *Emil Žagar*	Convergence of Increasingly Flat Radial Basis Interpolants to Polynomial Interpolants *Jungho Yoon*
15.10	Break	
	Chair: Richard Riesenfeld	
15.20	Invited Talk: Isogeometric Analysis: Progress and Challenges *Thomas J.R. Hughes*	
16.10	Coffee	
	Isogeometric Analysis *Chair: Trond Kvamsdal*	**Algebraic Geometry Methods** *Chair: Rimvydas Krasauskas*
16.30	N-widths, sup-infs, and optimality ratios for the k-version of the isogeometric finite element method *Yuri Bazilevs*	Linear precision for parametric patches *Frank Sottile*
17.00	Adaptive isogeometric analysis by local h-refinement with T-Splines *Bert Jüttler*	Rational envelopes of two-parameter families of spheres *Martin Peternell*
17.30	"Model Quality": The Mesh Quality Analogy for Isogeometric Analysis *Elaine Cohen*	Vertex blending via surfaces with rational offsets *Rimvydas Krasauskas*
18.00	CAD and iso-geometric analysis *Vibeke Skytt*	Computing the topology of algebraic curves and surfaces *Bernard Mourrain*
18.30	Talks End	
19.30	Welcome Barbecue on the Hotel Roof	

Friday 27. June, Morning Session

Time	Room I	Room II
	Chair: Ron Goldman	
8.30	Invited Talk: Polar varieties of real algebraic curves and surfaces *Ragni Piene*	
9.20	Coffee	
	Chair: Tom Hughes	*Chair: Ragni Piene*
9.50	Transfinite interpolation along parallel lines, based on splines in tension *Ziv Ayalon*	A closed formulae for the separation of two ellipsoids involving only six polynomials *Esmeralda Mainar*
10.10	Interpolation of a bidirectional curve network by B-spline surfaces on criss-cross triangulations *Paola Lamberti*	Approximating implicitly defined curves by fat arcs *Szilvia Béla*
10.30	Scattered Data Fitting using extended B-Splines *Jennifer Prasiswa*	Two Computational Advantages of Mu-Bases for the Analysis of Rational Planar Curves *Ron Goldman*
10.50	Adaptive Fitting of C^∞ Surfaces to Dense Triangle Meshes *M. Siqueira*	Multivariate Chebyshev Polynomials and Applications *Brett Ryland*
11.10	Break	
	Chair: Carla Manni	*Chair: Charles Loop*
11.20	Constructing good coefficient functionals for bivariate C^1 quadratic spline quasi-interpolants *Sara Remogna*	Subdivision Matrices of Normals and Jacobians for Surface and Volume Subdivision Schemes *Hiroshi Kawaharada*
11.40	A Non–Uniform Hermite Spline Quasi–Interpolation Scheme *Alessandra Sestini*	Subdivision schemes for ruled surfaces and canal surfaces *Boris Odehnal*
12.00	Extracting a Shape Descriptor for 3D Models by means of a Rotation Variant Similarity Measure *Michael Martinek*	Vector Field Subdivision *Thomas P. Y. Yu*
12.20	Lunch	

Friday 27. June, Afternoon Session

Time	Room I	Room II
	Chair: Panagiotis Kaklis	*Chair: Jesús M. Carnicer*
14.10	Generalized expo-rational B-splines *Lubomir T. Dechevsky*	A Topological Lattice Refinement Descriptor for Subdivision Scheme *François Destelle*
14.30	Generalized expo-rational B-splines for curves, surfaces, volume deformations and n-dimensional geometric modelling *A. R. Kristoffersen*	A Zoo of Special Features for ternary Catmull-Clark Subdivision Surfaces *Christoph Fuenfzig*
14.50	Generalized expo-rational B-splines and finite element methods for ODEs *Olga L. Pichkaleva*	Antagonism between Extraordinary Vertex and its Neighbourhood for Defining Nested Box-Splines *Cédric Gérot*
15.10	Break	
	Chair: Hans Hagen	
15.20	Invited Talk: Recent Techniques and Algorithms for High(er)-Quality Shape Design and Surface Representation *Jorg Peters*	
16.10	Coffee	
	Visualization *Chair: Charles Hansen*	**Constrained Representations** *Chair: Carla Manni*
16.30	Visualizing the Unknown *Min Chen*	An algorithm for computing the curvature-sign domain of influence of Bezier control points *Panagiotis Kaklis*
17.00	Generalized Voronoi Diagrams in Urban Planning *Hans Hagen*	Constrained T-spline Level Set Evolution *Bert Jüttler*
17.30	Interactive Visual Analysis of Timedependent Multivariate Data *Helwig Hauser*	Compactly Supported Splines with Tension Properties on a Regular Triangulation *Francesca Pelosi*
18.00	Interactive Texture Based Flow Visualization *Charles Hansen*	C^1 Blending of Wachspress Rational Patches *Aparajita Ojha*
18.30	Talks End	

Saturday 28. June, Morning Session

Time	Room I	Room II
	Chair: Malcolm Sabin	
8.30	Invited Talk: Interpolation and Compression of Image Data with Partial Differential Equations *Joachim Weickert*	
9.20	Coffee	
	Chair: Joachim Weickert	*Chair: Jorg Peters*
9.50	Uniform convergence of discrete curvatures on nets of curvature lines *Ulrich Bauer*	Approximation and Grid Generation using Subdivision Schemes *Karl-Heinz Brakhage*
10.10	Hexagonal meshes as discrete minimal surfaces *Christian Mueller*	Automated Generation of Finite Element Meshes Suitable for Floodplain Modelling *Andrew Goodwin*
10.30	On the Logarithmic Curvature and Torsion Graphs *Norimasa Yoshida*	The Adaptive Delaunay Triangulation - Properties and Proofs *Burkhard Lehner*
10.50	Local Shape of Classical and Generalized Offsets to Plane Algebraic Curves *Juan Gerardo Alcazar*	Numerical Solutions of the Kawahara and Modified Kawahara Equations Using Radial Basis Functions *Yilmaz Dereli*
11.10	Break	
	Chair: Charles Hansen	*Chair: Rimvydas Krasauskas*
11.20	Quadrangular Parameterization for Reverse Engineering *David Bommes*	From a single point to a surface patch by growing minimal paths *Fethallah Benmansour*
11.40	Computing the intersection with ringed surfaces *Mario Fioravanti*	Implicit shape reconstruction using a variational approach *Serena Morigi*
12.00	Finite multisided surface fillings *Kęstutis Karčiauskas*	Classification with Gaussians and Convex Loss *Daohong Xiang*
12.20	Lunch	

Saturday 28. June, Afternoon Session

Time	Room I	Room II
	Chair: Paolo Costantini	*Chair: Trond Kvamsdal*
14.10	Bézier approximation to Surfaces of Constant Mean Curvature *Rubén Dorado*	Contextual Image Compression and Delaunay Triangulations *Laurent Demaret*
14.30	Rational spline developable surfaces *Leonardo Fernandez-Jambrina*	Normal multilevel triangulations for geometric image compression *Ward Van Aerschot*
14.50	Support Function Representation of Surfaces for Geometric Computing *Maria Lucia Sampoli*	Interpolation using scaled Gaussian Radial Basis functions *Marshall Walker*
15.10	Break	
	Chair: Elaine Cohen	
15.20	Invited Talk: Delaunay refinement for manifold approximation *Jean-Daniel Boissonnat*	
16.10	Coffee	
	Subdivision *Chair: Bin Han*	*Chair: Lubomir Dechevsky*
16.30	Subdivision Schemes and Seminormed Spaces *Serge Dubuc*	Newton-Cotes cubature rules over $(d+1)$-pencil lattices *Vito Vitrih*
17.00	Blending Based Corner Cutting Subdivision Scheme for Nets of Curves *Costanza Conti*	Numerical Integration over Spherical Caps *Kerstin Hesse*
17.30	Multiresolution analysis for minimal C^r-surfaces on Powell-Sabin type meshes *M.J. Moncayo*	Sampling Inequalities and Applications *Christian Rieger*
18.00	Convergence of Subdivision Schemes with Hoelder Continuous Masks and its Applications *Bin Han*	Hyperinterpolation in the cube *Stefano De Marchi*
18.30	Talks End	

Monday 30. June, Morning Session

Time	Room I	Room II
	Chair: Paul Sablonnière	
8.30	Invited Talk: Variational principles and compressive algorithms *Massimo Fornasier*	
9.20	Coffee	
	Chair: Jean-Daniel Boissonnat	*Chair: Massimo Fornasier*
9.50	Planar rational quadratics and cubics: parametrization and shape control *Gudrun Albrecht*	First applications of a formula for the error of finite sinc interpolation *Jean-Paul Berrut*
10.10	Partial Differential Equations for Interpolation and Compression of Surfaces *Egil Bae*	Learning Rates of Moving Least-square Regression in a Finite Dimensional Hilbert Space *Hongyan Wang*
10.30	Mean distance from a curve to its control polygon *Jesús M. Carnicer*	An Improved Error Bound for Gaussian Interpolation *Lin-Tian Luh*
10.50	A point-based Clenshaw-Curtis type algorithm for computing curve length *Atgeirr F. Rasmussen*	Gradient Learning in a Classification Setting by Gradient Descent *Jia Cai*
11.10	Break	
	Chair: Emil Žagar	*Chair: Bin Han*
11.20	New Quasi-interpolants Based on Near-Best Discrete Spline Quasi-interpolants on Uniform Triangulations *D. Barrera*	Generalization of Midpoint Subdivision *Qi Chen*
11.40	From PS splines to QHPS splines *Hendrik Speleers*	Curvature Continuity at Extraordinary Vertices *Charles Loop*
12.00	Shape preserving Hermite interpolation by rational biquadratic splines *Sablonnière Paul*	Continuity analysis of double insertion, non-uniform, stationary Subdivision Surfaces *Kerstin Mueller*
12.20	Lunch	

Monday 30. June, Afternoon Session

Time	Room I	Room II
	Chair: Domingo Barrera	*Chair: Adi Levin*
14.10	Weighted semiorthogonal spline wavelets and applications *Mario Kapl*	The parametric four point scheme *Kai Hormann*
14.30	Anisotropic methods for restoring rotated and sheared rectangular shapes *Tanja Teuber*	Non-uniform interpolatory subdivision designed from splines *Lucia Romani*
14.50	Natural Neighbor Extrapolation *Tom Bobach*	Convergence and Smoothness Analysis of Nonlinear Stationary Subdivision Schemes in the Presence of Extaordinary Points *Andreas Weinmann*
15.10	Break	
	Chair: Gerald Farin	
15.20	Invited Talk: Tetrahedral Meshes with Good Dihedral Angles *Jonathan Shewchuk*	
16.10	Coffee	
	Radial Basis Functions *Chair: Oleg Davydov*	**Heterogeneous Computing** *Chair: Tor Dokken*
16.30	Computational issues in RBF fitting *Rick Beatson*	Geometry Processing and Hetrogeneous Computing *Tor Dokken*
17.00	Non-regular surface approximation *Mira Bozzini*	Parallel Example-based Texture Synthesis for Surfaces *Sylvain Lefebvre*
17.30	Approximation on two-point homogeneous manifolds *Jeremy Levesley*	A Comparison of Three Commodity-Level Parallel Architectures: Multi-core CPU, the Cell BE and the GPU *André Rigland Brodtkorb*
18.00	Scattered Data Reconstruction of Radon Data for Computer Tomography *Wolfgang zu Castell*	Simplification of FEM-models on multi-core processors and the Cell BE *Jon Hjelmervik*
18.30	Talks End	

Tuesday 1. July, Morning Session

Time	Room I	Room II
	Chair: Serge Dubuc	
8.30	Invited Talk: Conformal Equivalence of Triangle Meshes *Peter Schroeder*	
9.20	Coffee	
	Chair: Jonathan Shewchuk	*Chair: Peter Schroeder*
9.50	Detecting and Preserving Sharp Features in Anisotropic Smoothing for Noised Mesh *Masatake Higashi*	Computing n-variate orthogonal discrete wavelet transforms on the GPU *Joakim Gundersen*
10.10	Stochastic resonance in quantized triangle meshes *Ioannis Ivrissimtzis*	Computing multivariate intersections on the GPU. *Børre Bang*
10.30	Tensor Product B-Spline Mesh Generation for Accurate Surface Visualizations in the NIST Digital Library of Mathematical Functions *Bonita Saunders*	Scattered data approximation on $SO(3)$ *Dominik Schmid*
10.50	Online Triangulation of Laserscan Data *Klaus Denker*	A greedy algorithm for adaptive hierarchical anisotropic triangulations *Jean-Marie Mirebeau*
11.10	**End of Conference**	

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Abstracts

Planar rational quadratics and cubics: parametrization and shape control

Gudrun Albrecht
University of Valenciennes

Monday 9.50, I

This talk is concerned with planar rational curves of degree two and three, and addresses the following two issues:

In the case of *rational quadratics* a simple analytical solution to the problem of determining the optimal parametrization is given. Optimality is measured with respect to arc length by means of the L_2–norm. The presented result is based on a method of Farouki [1] and J [2], who solve the optimal parametrization problem analytically in the case of *polynomial* curves, but suggest a numerical procedure for *rational* curves. This is joint work with I. Cattiaux-Huillard and V. Hernandez-Mederos.

In the case of planar *rational cubics* the issue of determining inflection points and singularities is dealt with. Given a planar cubic in standard Bézier form based on the work of Sakai [3], the distribution of its characteristic points (inflection points, cusps, loops) is determined, depending not only on the position of the control points, but also on the variable two inner weights. This is joint work with J.P. Bécar and X. Xiang.

[1] R. T. Farouki, Optimal parameterizations, Computer Aided Geometric Design, 14, 153-168, 1997.

[2] B. J, A vegetarian approach to optimal parameterizations, Computer Aided Geometric Design, 14, 887-890, 1997.

[3] M. Sakai, Inflection points and singularities on planar rational cubic curve segments, Computer Aided Geometric Design, 16, 149-156, 1999.

Local Shape of Classical and Generalized Offsets to Plane Algebraic Curves

Juan Gerardo Alcazar
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Saturday 10.50, I

In order to determine the situations where the offsetting process introduces local changes (like for example cusps arising from regular points), Differential Geometry can be directly applied whenever the starting curve has no singularities. When the initial curve has singularities, the alternative notion of **local shape** can be used in order to study the effect of the offsetting process on them. This notion basically corresponds to a description of the local behavior of a curve around a real point. Here we will review this notion, and we will compare the main properties concerning the shape of **classical offsets** (i.e. the usual notion of offset curve considered in the literature) and of **generalized offsets**, introduced by Arrondo, Sendra and Sendra, for the case of algebraic curves. Essentially, fixed a distance d and an angle θ, the generalized offset of a curve $\mathcal{C}$ is the geometrical object obtained by applying the following construction to $\mathcal{C}$: for each point $P \in \mathcal{C}$, take the normal line to $\mathcal{C}$ at P, rotate it θ degrees, and mark the points in this line lying at a distance d of P. In this sense, by using classical elements of Differential Geometry we will show that while classical offsets of regular curves tend to have real cusps, generalized offsets do not, but may have inflections instead. Also, by using the notion of local shape, we will see that a more intricate behavior at singularities is observed in the generalized case compared with the classical one.

Transfinite interpolation along parallel lines, based on splines in tension

Ziv Ayalon, Nira Dyn and David Levin
Tel Aviv University

Friday 9.50, I

In this talk we discuss the problem of interpolating data, sampled from a bivariate function, along the parallel lines $\{x_i\} \times [-\pi, \pi]$, $i = 0, 1, ..., N$, $x_0 < x_1 < \cdots < x_N$. This problem has a unique solution in the rectangle $[x_0, x_N] \times [-\pi, \pi]$ if the interpolant is required to satisfy certain partial differential equations in the rectangular domains between the interpolation lines. A known such method is that of the polyharmonic polysplines. We suggest a new choice of partial differential equations that results in better interpolants, with satisfactory smoothness and reproduction properties.

The interpolating function is constructed from sets of Fourier coefficients defined for each $x \in [x_0, x_N]$, which are the interpolants by splines in tension to the corresponding Fourier coefficients of the data. The novelty in our method is that the resulting interpolant inherits the flexibility of the splines in tension, in the sense that its tightness in each rectangular domain $[x_i, x_{i+1}] \times [-\pi, \pi]$ can be controlled.

Our interpolation method is shown to produce interpolants that minimize a certain energy functional. We also derive L^2 error bounds for our method, based on new L^2 error bounds for splines in tension. We illustrate the theoretical results by numerical examples. Our interpolation method is compared with two known methods, and its superiority is demonstrated.

Partial Differential Equations for Interpolation and Compression of Surfaces

Egil Bae
Department of Mathematics, University of Bergen

Monday 10.10, I

In this talk we present geometric partial differential equations (PDEs) for interpolation and approximation of surfaces from scattered point sets. Triangulated surfaces are used as discrete representation, and the PDEs are discretized by the finite element method directly on the triangular meshes.

As a main application, a new PDE based method for lossy compression of triangulated surfaces is presented. The coding step selects a suitable small subset of the vertices (geometry) to be stored, while the decoding step uses PDE based interpolation to reconstruct the surface from the stored vertex set.

This work is inspired from promising image interpolation and compression methods, recently proposed by Irena Galic and Joachim Weickert et. al.

Computing multivariate intersections on the GPU.

Børre Bang, Lubomir T. Dechevsky, Joakim Gundersen, Arnt R. Kristoffersen and Arne Lakså
Narvik University College

Tuesday 10.10, II

In [1],[2] was proposed a method for isometric immersion of smooth m-variate n-dimesional vector fields, m=1,2,3,4,... n 1,2,3,4,... onto fractal curves and surfaces, thereby creating an opportunity to process high-dimensional geometric data on the GPU. For this construction, the structure of multivariate tensor-product orthonormal wavelet bases was of key importance. In [1] and [2] we also discussed the spatial localization of points in high dimensional space and their images on the plane (resp., pixel in image, processed by the GPU). In the present work we show how to compute approximately on the GPU multivariate intersection manifolds, using the above wavelet based construction and mapping algorithm. We discuss the following stages of the computation.

(A) Computing intersection points in the plane (as pixels in the image) and finding the point cloud in high dimensional space which corresponds to this pixel (both the position and the value of the pixel are used in the mapping algorithm).

(B) Given the intersecting manifolds (assumed compact), we find a a volume of minimal dimension containing the manifolds. We establish isometric mapping between this volume and the planar image on the GPU. This mapping uniquely defines also the images of the co-ordinates lines in the volume onto the plane. This enables us to define a topology in the planar image of the scattered point cloud found in item (A).

(C) Using the inverse (adjoint) orthogonal mapping, we introduce a "wire-frame" ordering in the point cloud of the solution, thus, obtaining the numerical approximation to the solution manifold.

(D) The precision of the result obtained can be verified by direct computation of the intersection conditions.

Reference:

[1] L.T.Dechevsky, J. Gundersen. Isometric Conversion Between Dimension and Resolution. Mathematical Methods for Curves and Surfaces: Tromsø 2004 Editors M. Dæhlen, K. Mørken and L. Schumaker

[2] L.T.Dechevsky, J. Gundersen, A. Kristoffersen. Wavelet-based Isometric Conversion between Dimension and Resolution and Some of Its Applications. Wavelet Application in Industrial Processing V, edited by Frédéric Truchetet, Olivier Laligant, Proc. of PSIE Vol. 6763, 67630Q, (2007)

New Quasi-interpolants Based on Near-Best Discrete Spline Quasi-interpolants on Uniform Triangulations

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Monday 11.20, I

We propose new schemes based on C^1 and C^2-splines on uniform triangulations for approximating functions defined on the real plane $\mathbb{R}^2$.

From a near best discrete quasi-interpolant Q_d based on a B-spline and exact on the space $\mathbb{P}_k$ of polynomials of maximal total degree k included in the space spanned by the integer translates of the B-spline, we construct new differential quasi-interpolants Q_D exact on $\mathbb{P}_{k+1}$, by considering the derivatives of the function to be approximated. The new quasi-interpolants differ from the existing in the literature. They are defined by a simple modification of the original operator.

When the derivatives are not available, we can approximate them by using finite differences, and then new discrete quasi-interpolants $\widetilde{Q}_d$ result.

We estimate the quasi-interpolation errors $f - Q_D f$ and $f - \widetilde{Q}_d f$ in the infinity norm.

Computing envelope approximations using MOS surfaces

Bohumír Bastl, Bert Jüttler, Jiří Kosinka and Miroslav Lávička
University of West Bohemia, Pilsen, Czech Republic
Johannes Kepler University, Institute of Applied Geometry, Linz, Austria
University of Oslo,Centre of Mathematics for Applications, Oslo, Norway

Thursday 11.20, I

The talk will present an algorithm for computation of rational envelope approximations of two-parameter families of spheres of quadratic MOS surfaces (quadratic triangular Bézier patches in $\mathbb{R}^{3,1}$). Generally, MOS surfaces are rational surfaces in $\mathbb{R}^{3,1}$ which provide rational envelopes of the associated two-parameter family of spheres (see Kosinka, Jüttler: *MOS surfaces: Medial Surfaces Transforms with Rational Domain Boundaries*. Mathematics of Surfaces 2007: 245-262). Recently, it has been proved that quadratic triangular Bézier patches in $\mathbb{R}^{3,1}$ possess this property, i.e., they belong into the class of MOS surfaces (see Peternell, Odehnal, Sampoli: *On quadratic two-parameter families of spheres and their envelopes*. Computer Aided Geometric Design, to appear). In this talk we give a direct proof of this fact and formulate an algorithm for computing the parametrization of a quadratic triangular Bézier patches in $\mathbb{R}^{3,1}$ fulfilling the MOS condition. Since these patches are capable of producing C^1 smooth approximations of medial surface transforms of spatial domains, we use this algorithm to generate rational approximations of envelopes of general medial surface transforms. The algorithm contains three main steps: 1. determination of points with parallel isotropic normal vectors on patches and subdivision along their preimages, 2. finding a rational quadratic triangular Bézier patch on the sphere circumscribing the locus of all isotropic normal vectors of the patch, 3. finding the rational parametrization of the envelope and the exact parametric domains. The algorithm will be demonstrated on several examples.

Uniform convergence of discrete curvatures on nets of curvature lines

Ulrich Bauer, Konrad Polthier and Max Wardetzky
FU Berlin

Saturday 9.50, I

For the discretization of a smooth surface by a discrete net of curvature lines, we prove uniform *pointwise* convergence of a broad class of well-known edge-based discrete curvatures to smooth principal curvatures. Our proofs use explicit error bounds, with constants depending only on the maximum curvature, the derivative of curvature of the smooth surface, and the form regularity of the discrete net.

One important aspect of our result is that the error bound is independent of the geodesic curvature of the curvature lines, and therefore is also applicable in the vicinity of umbilical points. This is the first pointwise convergence result for discrete curvatures that is applicable to general discrete surfaces.

N-widths, sup-infs, and optimality ratios for the k-version of the isogeometric finite element method

Ivo Babuska, **Yuri Bazilevs**, John Evans and Thomas Hughes
ICES, UT Austin

Thursday 16.30, I

We begin the mathematical study of the k-method utilizing the theory of Kolmogorov n-widths. The k-method is a finite element technique where spline basis functions of higher-order continuity are employed. It is a fundamental feature of the new field of isogeometric analysis. In previous works, it has been shown that using the k-method has many advantages over the classical finite element method. In application areas such as structural dynamics, wave propagation, and turbulence.

The Kolmogorov n-width and sup-inf were introduced as tools to assess the effectiveness of approximating functions. In this work, we investigate the approximation properties of the k-method with these tools. Following a review of theoretical results, we conduct a numerical study in which we compute the n-width and sup-inf for a number of one-dimensional cases. This study sheds further light on the approximation properties of the k-method. Comparison study of the k-method and the classical finite element method and an analysis of the robustness of polynomial approximation are also performed.

Computational issues in RBF fitting

Rick Beatson
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Monday 16.30, I

The RBF ansatz has application to a wide number of related problems, including interpolating point values, Hermite interpolation, fitting divergence free vector fields, fitting correlated attributes, etc. There are a number of issues that arise repeatedly when trying to apply these methods to large noisy datasets. In this talk some of these computational issues will be identified and techniques which at least partially overcome them discussed.

One example is the choice of heuristic for a greedy linear least squares fit. In such a problem one wants to fit with as few active centres as possible, such a parsimonious fit having much less chance of following the noise. In an application involving divergence free polyharmonic RBFs the heuristic of maximum 2-norm residual performed very poorly. A simple replacement which can be implemented in many other adaptive linear least squares contexts will be discussed.

Approximating implicitly defined curves by fat arcs

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Friday 10.10, II

In the case of planar parametric curves, fat arcs were used by Sederberg (CAGD, 1989) as bounding primitives. They are defined by an approximating circular arc with a certain thickness. Instead of parametric curves, we consider algebraic curves, which are given as the zero set of a bivariate polynomial in Bernstein-Bézier representation. For this class of curves, we present an algorithm for bounding them by a collection of fat arcs.

The algorithm combines a local approximation step for an algebraic curve segment in a box with an adaptive subdivision strategy. Depending on the user-specified tolerance, it creates more or less fat arcs that enclose the curve. We experimentally analyze the convergence rate of the fat arcs and compare them with enclosing boxes. In addition we discuss potential applications, such as polynomial system solving and certified tracing of surface-surface intersections.

A practical approach for optimal Multi-Degree Reduction of Bezier offsets curves

Idir Belaidi and Kamal Mohammedi
UMB Boumerdes, algiers

The developed approach for an optimal multi-degre reduction of Bezier offsets curves proposed here is based on the inverse principle of the degree elevation algorithm and the minimization of the standard mean square in the Bernstein polynomials base . The strategy of resolution of the problem by variable separation introduced here allows a multi-reduction of degree of Bzier offsets curves in a single step, by ensuring a minimal approximation error and a maximum continuity at the extreme control points, by avoiding the use of nonlinear numerical methods. The flexible conversion in the other models (rational Bzier abd B-spline curves and surfaces) without sophisticated calculation is in fact another practical advantage of this approach.

From a single point to a surface patch by growing minimal paths

Fethallah Benmansour and Laurent D. Cohen
Universit Paris-Dauphine, Ceremade, CNRS, UMR7534, F-75016 Paris, France

Saturday 11.20, II

We introduce a novel implicit approach for surface patch segmentation in 3D images starting from a single point. Since the boundary surface of an object is locally homeomorphic to a disc, we know that the boundary of a small neighboring domain intersects the surface of interest on a single closed curve. Similarly to active surfaces, we use a cost potential which penalizes image regions of low interest. First, Using a front propagation approach from the source point chosen by the user, one can see that the closed curve corresponds to valley lines of the arrival time from the source point. Next, we use a recently introduced implicit 3D segmentation method. It assumes that the object boundary contains two known constraining curves. In our case, the first curve is reduced to a point and the other one is automatically detected by our approach. A partial differential equation is introduced and its solution is used for segmentation. The zero level set of this solution contains valley lines and the source point as well as the set of minimal paths joining them. We present a fast implementation which has been successfully applied to 3D medical and synthetic images.

First applications of a formula for the error of finite sinc interpolation

Jean-Paul Berrut

Monday 9.50, II

We consider the interpolation of a function $f \in C^{2m+2}(\mathrm{R})$ between the equidistant abscissae $x_n = nh, h > 0, n \in \mathrm{Z}$. Sinc–interpolation is based on a dilation and a series of shifts of the sinus–cardinalis function $\mathrm{sinc}(x) := \sin(x)/x$. It often converges very rapidly, so for example for functions analytic in an open strip containing the real line and which decay fast enough at infinity. This decay does not need to be very rapid, however, as in Runge's function $1/(1+x^2)$. Then one must truncate the series, and this truncation error is much larger than the discretisation error (it decreases algebraically as opposed to exponentially for the latter).

In 2003 we have discovered a formula for the error $C_N(f,h) - f$ of the truncated series

$$C_N(f,h)(x) := \sum_{n=-N}^{N}{}'' \,\mathrm{sinc}\left[\pi h(x - x_n)\right] f_n, \qquad h = \frac{X}{N},$$

for an approximation on the interval $[-X, X]$, where the double prime means that the first and last terms are halved. The formula reads

$$C_N(f,h)(x) = f(x) + \frac{(-1)^N}{2\pi}\sin(\frac{\pi}{h}x)\sum_{k=1}^{m} a_{2k}(x)(2h)^{2k} + \mathcal{O}(h^{2m+2}),$$

with

$$a_{2k}(x) := 2(1-2^{-2k})\frac{B_{2k}}{(2k)!}\left[\left(\frac{f(y)}{x-y}\right)^{(2k-1)}(X) - \left(\frac{f(y)}{x-y}\right)^{(2k-1)}(-X)\right]$$

and where the B_k denote the Bernoulli numbers.

In our talk we shall give first applications of the formula, such as its

use for correcting $C_N(f,h)$ with derivatives and finite differences, the barycentric formula, extrapolation to the limit and an error formula for one-sided sinc-interpolation.

Natural Neighbor Extrapolation

Tom Bobach, Gerald Farin, Dianne Hansford and Georg Umlauf
University of Kaiserslautern
Arizona State University

Monday 14.50, I

Extrapolating a function usually amounts to educated guessing outside the convex hull of known data. Where global scattered data interpolation and approximation such as radial basis functions or tensor product spline fitting naturally allows extrapolation to some extent, local methods do not.

We focus on natural neighbor concepts to define a framework for smooth local extrapolation of data defined over point sets that seamlessly blends with classical natural neighbor interpolation schemes. Each application dictates its own notion of feasible behaviour outside the convex hull: shall the function stay constant or follow the last observed trend linearly? Our framework provides such control over the extrapolant away from the convex hull.

Delaunay refinement for manifold approximation

Jean-Daniel Boissonnat
Inria Sophia Antipolis Mediterranee

Saturday 15.20

Delaunay refinement is a greedy technique for constructing provably good approximations of manifolds of small dimensions. The talk will cover some recent results in surface and volume mesh generation, anisotropic mesh generation and manifold reconstruction. The algorithms rely on the concept of Delaunay triangulation restricted to a manifold and on the related concept of witness complex introduced by de Silva.

Quadrangular Parameterization for Reverse Engineering

David Bommes, Leif Kobbelt and Tobias Vossemer
RWTH Aachen University

Saturday 11.20, I

For complex geometric objects, a parametrization is usually computed in a piecewise manner, i.e. the given surface is decomposed into disjoint patches and a local parametrization is computed for each of them. Since for technical objects, a segmentation into rectangular patches is preferred, a natural choice for the local parameter domains is the unit square.

The difficulty of the piecewise parametrization problem emerges from the smoothness conditions between neighboring patches which turns the local parametrization task into a global problem.

Another challenge is the prevention of non-injectivities (foldovers) which tend to appear in regions where the geometric shape of a patch deviates significantly from the shape of the domain or when neighboring patches have very incompatible shapes. Hence, globally smooth parametrization schemes often include a relaxation step where the patch layout is adapted such that local foldovers are effectively prevented. However, the obvious drawback of the relaxation procedure is that patch boundaries are changed. This is critical if the boundaries represent certain geometric features of the input (or should be aligned to them). Moreover, geometric shapes may not allow a decomposition into almost rectangular patches.

In our paper we therefore use an alternative approach. Instead of changing the patch layout, we change the parameter domains. We generalize the square domains to arbitrary quadrilaterals. This is obtained by using more general transition functions between neighboring patches. The optimal domains, i.e. the domains that cause a minimum distortion, are found in an efficient non-linear optimization scheme. To provide full control over the resulting parametrization we additionally enable user-selected alignment and tangential continuity constrains.

Non-regular surface approximation

Mira Bozzini, Licia Lenarduzzi and Milvia Rossini
Dipartimento di Matematica e Applicazioni, Università di Milano-Bicocca, via Cozzi 53, 20125 Milano, Italy
IMATI-CNR , via Bassini 15, 20133 Milano, Italy

Monday 17.00, I

One of the relevant problems in the geospatial information system is the cartographic reconstruction of surfaces presenting particular features that can be described as discontinuities in the function or in its derivatives.

The aim of the talk is to discuss this problem considering some computational examples achieved by strategies based on TPS for the recovering, and suitable procedures for the detection and reconstruction of the discontinuity curves.

Approximation and Grid Generation using Subdivision Schemes

Karl-Heinz Brakhage
Institut für Geometrie und Praktische Mathematik, RWTH Aachen

Saturday 9.50, II

Subdivision surfaces are normally used for modeling in CAGD and in Computer Graphics. Our aim is to solve interpolation and approximation problems with this methods. Thus we do not only need values at certain points but also need the coefficients of the involved mesh points to end up with a sparse linear system for an initial mesh. In case of the Catmull-Clark scheme we give a detailed analysis to set up the system needed for solving the least squares problem, which can be solved efficiently by iterative methods. Furthermore we will demonstrate how this concept is used for the generation of numerical grids for realistic wing-fuselage configurations in the Collaborative Research Center SFB401 *Flow Modulation and Fluid Structure Interaction at Airplane Wings* at the RWTH Aachen.

A Comparison of Three Commodity-Level Parallel Architectures: Multi-core CPU, the Cell BE and the GPU

André Rigland Brodtkorb and Trond Runar Hagen
SINTEF ICT, Department of Applied Mathematics
SINTEF ICT, Department of Applied Mathematics and Centre of Mathematics for Applications, University of Oslo

Monday 17.30, II

We explore three widespread parallel architectures: multi-core CPUs, the Cell BE processor, the graphics processing units. We have implemented four algorithms on these three architectures: the heat equation, inpainting using the heat equation, computing the Mandelbrot set, and MJPEG movie compression. We use these four algorithms to exemplify the benefits and drawbacks of each parallel architecture.

Hermite Mean Value Interpolation in $\mathbb{R}^n$

Solveig Bruvoll
Institute of Informatics, University of Oslo

Thursday 9.50, I

In this talk we explain the concept of hermite mean value interpolation in R^n. By deriving the normal derivative of the lagrange mean value interpolant and of a mean value weight function we construct a transfinite hermite interpolant, under some conditions on the boundary of our domain.

Finally, we study an application of hermite mean value interpolation in R^3. When modelling the blood flow in the human body, some PDEs are solved. To avoid having to solve these PDEs on every individually shaped part of the blood vessels, we want to solve the PDEs on some standard shapes. These shapes are in turn deformed and combined to form the complete blood vessels. For this deformation, the hermite mean value interpolation is used.

Gradient Learning in a Classification Setting by Gradient Descent

Jia Cai, Hongyan Wang and Dingxuan Zhou

Monday 10.50, II

Learning gradients is one approach for variable selection and feature covariation estimation when dealing with large data of many variables or coordinates. In a classification setting involving a convex loss function, a possible algorithm for gradient learning is implemented by solving convex quadratic programming optimization problems induced by regularization schemes in reproducing kernel Hilbert spaces. The complexity for such an algorithm might be very high when the number of variables or samples is huge. In this paper we introduce a gradient descent algorithm for gradient learning in a classification setting. The implementation of this algorithm is simple and its convergence is elegantly studied. Explicit rates for learning a classification function and its gradient are presented in terms of the regularization parameter and the step size. Deep analysis for approximation by reproducing kernel Hilbert spaces under some mild conditions on the probability measure for sampling allows us to deal with a general class of convex loss functions.

Mean distance from a curve to its control polygon

Jesús M. Carnicer and Jorge Delgado
University of Zaragoza, Spain
University of Oviedo, Spain

Monday 10.30, I

In Computer-Aided Geometric Design, parametric curves

$$\gamma(t) = \sum_{i=0}^{n} P_i, u_i(t), \quad t \in [a,b],$$

are generated by *blending systems* of functions $(u_0, \ldots, u_n)$,

$$u_i : [a,b] \to \mathbb{R}, \quad u_i(t)0 \quad i = 0, \ldots, n, \quad \sum_{i=0}^{n} u_i(t) = 1, \quad t \in [a,b].$$

The polygon $P_0 \cdots P_n$ is called the *control polygon* of the curve γ.

We are interested in providing a measure of the degree of approximation of a parametric curve by its control polygon. This problem has been previously studied in [1], [2] and [3]. We will obtain bounds for the mean distance between two parametric curves and, in particular we will bound the mean distance between a parametric curve and its control polygon. We shall study the important case of Bézier curves and provide an estimation of the signed area between a Bézier curve and its control polygon.

References

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[3] Reif, U., Best bound on the approximation of polynomials and splines by their control structure. Computer Aided Geometric Design **17**, 579–589 (2000).

Visualizing the Unknown

Min Chen
Swansea University

Friday 16.30, I

In this talk, the speaker will consider several scenarios where the data to be visualized is incomplete, of a lower quality or even largely unknown. It is arguable that such scenarios are in fact present in most visualization tasks, and many visualization techniques have been developed to deal with incomplete data and low quality data.

A data-driven approach is a possible solution to address the problem of visualizing the unknown. In particular, the speaker will examine two scientific problems, and will present a line of reasoning that data modeling is part of a solution to such a visualization problem. The discussion can lead to a generalization of similar problems and methodologies in visualization, and encourage the broadening of the scope of visualization research.

Generalization of Midpoint Subdivision

Qi Chen and Hartmut Prautzsch
Universität Karlsruhe (TH), Germany

Monday 11.20, II

It has been shown by the authors by a geometric method in 2007, that the limiting surfaces of midpoint subdivision are C^1-continuous. This method is used to show that certain generalizations of the midpoint subdivision scheme generate C^1-continuous limiting surfaces. In particular, this covers the Catmull-Clark algorithm.

"Model Quality": The Mesh Quality Analogy for Isogeometric Analysis

Elaine Cohen, Robert M. Kirby, Tom Lyche, Tobias Martin and Richard Riesenfeld
Schoolf of Computing, University of Utah
School of Computing, University of Utah
CMA and Institut for Informatics, University of Oslo

Thursday 17.30, I

Isogeometric analysis has been proposed as a methodology for bridging the gap between Computer Aided Design (CAD) and Finite Element Analysis (FEA). Although both the traditional and isogeometric pipelines rely upon the same conceptualization to solid model steps, they drastically differ in how they bring the solid model both to and through the analysis process. The isogeometric analysis process circumvents many of the meshing pitfalls experienced by the traditional pipeline by working directly within the approximation spaces used by the model representation. In this talk we discuss issues relating to understanding the differences.

Blending Based Corner Cutting Subdivision Scheme for Nets of Curves

Costanza Conti and Nira Dyn
Dipartimento di Energetica “Sergio Stecco”, Universita’ di Firenze, Italy
School of Mathematical Sciences, Tel Aviv University, Israel

Saturday 17.00, I

In this talk we present a new subdivision procedure which repeatedly refines nets of curves in R^3 and generates a limit surface. The scheme is an improvement of the BC-algorithm (Blending-Chaikin algorithm) proposed by us in the Tromso meeting. While the BC-algorithm generates C^0 limit surfaces, by adding a step at each refinement level, which "cuts the corners" of the curves generated by the refinement step of the BC-algorithm, we obtain a scheme which converges to C^1 limit surfaces. The performance of the new scheme on some examples will be demonstrated.

Error bounds for anisotropic RBF interpolation

Oleg Davydov
University of Strathclyde

Thursday 11.20, II

We prove local error bounds for the interpolation with anisotropically scaled radial basis functions of finite smoothness, such as thin plate splines or compactly supported RBFs. The bounds are in terms of scaled directional derivatives and are useful for the estimation of the accuracy of two stage scattered data fitting methods, where different anisotropies occur in different parts of the domain. This is a joint work with Rick Beatson and Jeremy Levesley.

Hyperinterpolation in the cube

Stefano De Marchi, Marco Vianello and Yuan Xu
Department of Computer Science, University of Verona, Verona (Italy)
Department of Pure and Applied Mathematics, University of Padova, Padova (Italy)
Department of Mathematics, University of Oregon, Eugene (USA)

Saturday 18.00, II

We construct an hyperinterpolation formula of degree n in the three-dimensional cube, by using a new cubature formula for the product Chebyshev measure. The underlying function is sampled at $N \sim n^3/4$ points, whereas the hyperinterpolation polynomial is determined by its $(n+1)(n+2)(n+3)/6 \sim n^3/6$ coefficients in the trivariate Chebyshev orthogonal basis. The effectiveness of the method is shown by several numerical test s and an application to the surface compression.

Generalized expo-rational B-splines

Lubomir T. Dechevsky
Narvik University College

Friday 14.10, I

This is a concise overview of the latest progress in the theory of expo-rational B-splines (ERBS) (for an overview of earlier results, see [1]). Topically, the presentation is organized into 4 consecutive parts, as follows.

1. Definition and basic properties. ERBS can be defined, e. g., as uniformly bounded (stable) families of projections acting on a Banach space with Schauder bases, with an operator form of the basic properties considered in [1], and reducing certain compact operators to canonical Jordan (normal) form.

2. Applications to CAGD. Four, different but interrelated, constructions of ERBS-based C^∞-smooth Hermite interpolants of arbitrary, total or partial, order are considered for scattered point sets on domains $\Omega \subset R^n$ with uniformly continuous boundary $\partial\Omega$ and arbitrary topology of Ω. The first construction does not require tessellations or triangulations; the second one is for star-shaped tessellations; the third and fourth ones are for triangulations. In all cases, and for any topology of Ω, the generalized Vandermonde matrix is in Jordan normal form. The relevance of these constructions to Riemann normal (geodesic) coordinates ensure that all 4 constructions can be extended to manifolds.

3. Multilevel B-splines. The constructions in item 2 lead to minimally supported biorthonormal multi-resolution analysis generating unconditional bases in $C^\infty(\Omega)$ and simultaneously in all topological vector spaces continuously embedded in the distribution space $D'(\Omega)$.

4. Applications to finite element and finite volume methods. Stability issues are completely eliminated. For initial-value problems, the stiffness matrix is triangular (explicit methods). For boundary-value problems the stiffness matrix is bounded with minimal bandwidth.

Reference: [1] L.T.Dechevsky, A.Lakså, B.Bang. Expo-rational B-splines. Int. J. Pure Appl. Math., 27(3), (2006), 319-367.

Progressive iteration approximation property

Jorge Delgado and Juan Manuel Pena
Departamento de Matemticas, Universidad de Oviedo
Departamento de Matemtica Aplicada, Universidad de Zaragoza

Thursday 9.50, II

Let us consider a sequence of parameters $(t_i)_{i=0}^n$ and a sequence of points $(P_i)_{i=0}^n$ in $\mathbf{R}^2$ or $\mathbf{R}^3$ such that the point P_i is assigned to the parameter t_i for all $i = 0, 1, \ldots, n$. So, given a blending basis $(u_0, \ldots, u_n)$, we generate a starting curve as $\gamma^0(t) = \sum_{i=0}^n P_i^0, u_i(t)$ where $P_i^0 = P_i$ for $i = 0, 1, \ldots, n$. Then, by calculating the adjusting vector for each control point $\Delta_i^0 = P_i^0 - \gamma^0(t_i)$, and taking $P_i^1 = P_i^0 + \Delta_i^0$ for $i = 0, 1, \ldots, n$ we get the curve $\gamma^1(t) = \sum_{i=0}^n P_i^1, u_i(t)$. Iterating this process we can get a sequence of curves $(\gamma^k)_{k=0}^\infty$. Then, when the curve sequence converges to a curve interpolating the given initial sequence of points, the initial curve is said to have the progressive iteration approximation property (PIA from now on).

Qi et al. as well as de Boor showed (see [6] and [1]) that the uniform cubic B-spline basis satisfied the PIA. In [4] Lin et al. showed that the nonuniform cubic B-spline basis also satisfied the PIA and extended the property for surfaces, showing that the nonuniform cubic B-spline tensor product surface satisfied such property. It is well know that normalized totally positive bases are associated to shape preserving representations and that the normalized B-basis presents optimal shape preserving properties. In [5] Lin et al. proved that curves and tensor product surfaces generated by normalized totally positive bases satisfy the PIA. Finally, in [3] Delgado and Peña showed that the normalized B-bases provide the fastest convergence rates of the PIA for both curves and surfaces generated by normalized totally positive bases.

Here we will make a survey of the known results on the PIA. In addition, we will discuss the PIA property with other different representations like the Wang-Ball basis (see for example [2]), which is not totally positive, and with rational surfaces.

References

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[2] J. Delgado and J. M. Peña (2006), On the generalized Ball bases, Advances in Computational Mathematics 24, 263-280.

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Contextual Image Compression and Delaunay Triangulations

Laurent Demaret
Helmholtz Zentrum Mnchen

Saturday 14.10, II

We present new advances in image compression based on adaptive triangulations. Classical compression standards (JPEG,JPEG2000), based on spectral methods (Fourier, wavelets) do not provide optimal approximation rates for functions containing essential singularities supported on regular curves, corresponding to geometrical shapes of objects in natural images. Therefore fully non-linear geometric methods have become an increasingly important research topic in the field of image approximation. Among them adaptive thinning methods are based on continuous, piecewise affine functions on Delaunay triangulations [1] and provide very flexible and reduced approximations of functions. This work is concerned with the design and implementation of a new efficient compression scheme of the corresponding information, which makes use of local redundancies in the triangulation. In particular, suitable contextual encoding of the positions of the vertices and of the greyscale values is proposed, which takes into account the specific local geometrical structure of the triangulation and combines it with appropriate combinatorial encoding. Finally some results are shown where our method significantly outperforms both our prototype method [1] and JPEG2000 for some classical images, at low bitrates.

This is joint work with Armin Iske (University of Hamburg) and Wahid Khachabi.

Reference

[1] L. Demaret, N. Dyn, A. Iske Image Compression by Linear Splines over Adaptive Triangulations, Signal Processing Journal 86 (7), July 2006, 1604-1616

Online Triangulation of Laserscan Data

Klaus Denker, Burkhard Lehner and Georg Umlauf
TU Kaiserslautern

Tuesday 10.50, I

Hand-guided laser scanners are used in industry for reverse engineering

and quality measurements. It is difficult for the operator to cover the scanned object completely and uniformly. Therefore, an interactive display of the surface scanned so far can assist the operator in this task.

Our implementation creates a triangulation from the stream of scanned surface points online, i.e., the data points are added to the triangulation as they arrive. Areas scanned multiple times or with a higher point density result in a

finer mesh and a higher accuracy. Furthermore, the vertex density adapts to the estimated curvature, and

a level-of-detail feature can reduce the mesh density for fast rendering even on low-cost graphics hardware.

Numerical Solutions of the Kawahara and Modified Kawahara Equations Using Radial Basis Functions

İdris Dağ and **Yilmaz Dereli**
Eskişehir Osmangazi University, Eskişehir , Turkey
Anadolu University, Eskişehir , Turkey

Saturday 10.50, II

This study is carried out to investigate the numerical solutions of the Kawahara and Modified Kawahara equations by using the meshless method based on collocation with radial basis functions. The scheme is exhibited by studying travelling wave solution for both equations. Results of the meshless method with different radial basis functions are presented. The figures of error and wave motions for both equations are shown. It is seen that the radial basis function method can be used to obtain the numerical solutions of the Kawahara and Modified Kawahara equations.

A Topological Lattice Refinement Descriptor for Subdivision Scheme

François Destelle, Cédric Gérot and Annick Montanvert
Gipsa-lab

Friday 14.10, II

A subdivision process consists in a topological subdivision step followed by a geometric smoothing of the mesh vertices. The topological step can be described as a refinement on regular tiling lattices [ID04] or more generally as some local transformation descriptors [MR03]. The former classifies all the regular lattice topological transformations via a compact encoding; it defines the mapping between two unbounded regular lattices. The regular lattice descriptor is limited by the control mesh face type, the subdivided mesh must be composed of the same kind of faces. The latter describes some local topological transformations as the insertion of vertices in each face; their formalism defines a meta-scheme of subdivision surfaces. But these meta-schemes cannot describe a large number of regular schemes, as well as most of the rotative lattice descriptors.
In our work we generalize these meta-schemes. Our descriptor is locally defined by an integer triple which describes the number of inserted vertices relatively to the components of each face : vertices, edges and center. Our topological meta-scheme is coupled with a flexible connectivity descriptor, enhancing the modelization capabilities. It describes the schemes commonly used and it can build a variety of others, including some of the rotative schemes. The subdivision operators described here can be concatenated, leading to more complex topological descriptions.

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[MR03] Heinrich Mller and Markus Rips. “Another metascheme of subdivision surfaces”. Visualization and Mathematics III, pages 201-220, 2003.

Geometry Processing and Hetrogeneous Computing

Tor Dokken
SINTEF

Monday 16.30, II

As parallel computing resources have been too expensive for most of the CAGD community, efficient implementation of algorithms outside of High Performance Computing (HPC) has until a few years ago been following the sequential programming paradigm. Floating point operations in earlier processors lasted multiple clock cycles. Thus traditional implementations of, e.g., the Cox-de Boor algorithm are tailored to minimizing the amount of floating point operations. Current CPU chips have multiple processors cores (2, 4, 8, 12) each performing multiple floating point operations in a clock cycle. In addition graphical processor units (GPUs) have become programmable data stream processors having up to 480 processors. As most traditional algorithms have been developed with sequential computing in mind, the sequential nature is hard-coded into the algorithm. Accordingly systems for automatic parallelization of such algorithms can not be expected to be readily available. Therefore we should readdress the algorithmic approach to CAGD challenges to find approaches that are better suited for multi-core and data stream processors. The talk will look at some experiments performed using GPUs as computational resources, and look into other CAGD challenges that could benefit from parallel algorithms.

Bézier approximation to Surfaces of Constant Mean Curvature

Rubén Dorado and Javier Sánchez-Reyes
University of Jaén (Spain)
University of Castilla-la Mancha (Spain)

Saturday 14.10, I

Constant mean curvature surfaces are defined as the solution of partial differential equations with boundary conditions. Such surfaces minimize a certain objective function, for instance the area in the case of minimal surfaces, hence finding application in physics and engineering. Numerical techniques are usually preferred, yet they do not furnished the Bézier representation demanded by commercial CAD programs. As an alternative, we advocate a polynomial approximation, based on a Hermite interpolation over a triangular domain, thus expressible as a triangular Bézier patch.

Subdivision Schemes and Seminormed Spaces

Serge Dubuc

Saturday 16.30, I

We compare three criteria of convergence of subdivision schemes for curves. The first one has been found by Gregory, Dyn and Levin in the uniform case, and by Buhmann and Micchelli in the general case. The second one is proposed by the author. The last one, by Daubechies and Lagarias, covers only the uniform case. We relate these three criteria together by using specific seminorms for subdivision operators, seminorms that make them equivalent. In particular, the last two criteria are linked through the duality theory.

Rational spline developable surfaces

Leonardo Fernandez-Jambrina
Universidad Politecnica de Madrid, Spain

Saturday 14.30, I

In this talk construction of developable surfaces is reviewed within the NURBS framework. Previous results by Aumann and the author for Bézier and B-spline developable surfaces respectively are extended to the rational and rational B-spline cases.

The null total curvature requirement for developable surfaces translates into non-linear conditions for control points if one uses the standard NURBS formalism. Only cylinders and cones can be constructed in a straightforward way, but not the generic case. However, the publication of [Aumann(2003)] showed that it is possible to

solve the developability constraint for all degrees with a simple linear algorithm relating the control points of neighbouring cells in the net of the surface. Besides the extension to spline developable surfaces the formalism can be completed by assigning weights to the control points and therefore obtain NURBS developable surfaces.

The construction is grounded on the blossom of rational B-spline curves and is therefore compatible with related algorithms such as knot insertion.

However, the construction does not commute with degree elevation of the limiting curves of the developable surfaces. This fact can be used for further extending the use of the formalism.

Other geometric features such as the striction line of the developable surface can be easily calculates with this construction.

References

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Geometric Design 24, 189-199.

Computing the intersection with ringed surfaces

Mario Fioravanti and Laureano Gonzalez–Vega
Universidad de Cantabria

Saturday 11.40, I

A method for computing the intersection curve between a rational surface and a rational ringed surface is analyzed. A ringed surface obeys two polynomial equations of the form $f(x,y,z,u)=0$ and $g(x,y,z,u)=0$, being u the parameter of the directrix curve. This parameter can be easily eliminated by computing the resultant of f and g, with respect to u by using, for example, the Bézout matrix. This gives the implicit equation of the ringed surface. Substituting with the

components of the other surface parametrization, one obtains the implicit equation of a real algebraic plane curve, which is a projection of the intersection curve between both surfaces into the real affine plane. Next, the topology of this algebraic curve is determined by using the algorithms in [Gonzalez–Vega, L., Necula, I., *Efficient topology determination of implicitly defined algebraic plane curves,* Computer Aided Geometric Design **19** (2002), 719–743] or [Eigenwillig, A., Kerber, M., Wolpert, N., *Fast and Exact Geometric Analysis of Real Algebraic Plane Curves,* ISSAC'07, 151–158, ACM Press], which are based on the using of the Sturm–Habitch sequence. Once the topology of the curve is known and the geometric extraneous components arising are discarded, a suitable number of well chosen points in each component of the searched intersection curve may be computed by using standard numerical methods.

Variational principles and compressive algorithms

Massimo Fornasier
Johann Radon Institute for Computational and Applied Mathematics (RICAM),
Linz, Austria

Monday 8.30

Solutions of certain PDEs and variational problems may be characterized by "a few significant degrees of freedom", and one may want to take advantage of this feature in order to design efficient numerical solutions. Examples of such situations are ubiquitous: digital signal coding/decoding, compressed sensing, singular PDEs for image processing, crack modelling and free-discontinuity problems, viscosity solutions of Hamilton-Jacobi

equations. In the first part of the talk, we revise the role of variational principles, in particular L1-minimization, as a method for sparsifying solutions in several contexts. Then we address particular applications and numerical methods. We present the analysis of a superlinear convergent algorithm for L1-minimization based on iterative reweighted least squares. We show its improved performances in compressed sensing. A similar algorithm is then applied for the efficient solution of a system of singular PDEs for image recolorization in a relevant real-life

problem of art restoration. We conclude by presenting initial promising results in domain decomposition methods for singular PDEs, for which solutions may be discontinuous. The discontinuities may cross the interfaces of the domain decomposition patches. The crucial difficulty is the correct treatment of interfaces, with the preservation of crossing discontinuities and the correct matching where the solution is continuous instead. We discuss the convergence properties of the proposed method and several numerical examples both in 1D and 2D.

A Zoo of Special Features for ternary Catmull-Clark Subdivision Surfaces

Christoph Fuenfzig, Hans Hagen, Kerstin Mueller and Lars Reusche
TU Kaiserslautern

Friday 14.30, II

In general when dealing with subdivision surfaces, we want to obtain a smooth surface with a given set of subdivision rules. To jazz up the smooth model by stylistic elements, Hoppe et al introduced special features. Their kind of special features use the refinement rules of cubic B-Spline curves at tagged edges as well as vertices and produce, e.g., sharp edges, conicals, and darts in this way. We push the boundaries of the existing special features and give an artist new choices to deform the model and to reduce continuity in well-defined areas. Rational subdivision surfaces as well as the known rules with restricted masks are part of our set of special features rules. Also, a blend between the old and new rules is possible. We compare the various special features and give an overview of their capabilities.

Antagonism between Extraordinary Vertex and its Neighbourhood for Defining Nested Box-Splines

François Destelle, **Cédric Gérot** and Annick Montanvert
GIPSA-Lab, Grenoble University

Friday 14.50, II

A Box-Spline based subdivision scheme generates a smooth Box-Spline surface with an n-sided patch around each extraordinary vertex (EV) of the initial mesh. Every patch is made up with nested Box-Spline rings. More precisely, at each subdivision step, extraordinary rules define the control polyhedron of a new Box-Spline which extends continuously the regular part of the surface within the n-sided hole. These rings are also expected to converge smoothly onto the EV. Necessary and sufficient conditions for achieving C^n-continuity at the EV cannot be used in practice for defining the extraordinary rules. But some studies investigate shape properties at the limit or the convergence behaviour at the EV and provide useful conditions on the eigenvalues and the eigenvectors of the subdivision matrix.

In this work, we highlight the fact that if these conditions may produce appropriate behaviour at the EV, they can also damage the shape of the Box-Spline rings around it. More precisely we design extraordinary rules for Loop's scheme which fulfil all these conditions and produce rings with unsatisfactory shape. This work demonstrates that, if extraordinary rules are defined for the rings composed of vertices around an EV, a compromise must be reached between the behaviour of the Box-Spline rings expected for the EV and the one expected for the regular surrounding area. As future work we study how to design such a compromise which would take into account new evaluation of produced distortions.

Spatial polynomial curves with different Pythagorean structures and associated frames

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Dipartimento di Matematica "Ulisse Dini," Università degli Studi di Firenze, ITALY.

Thursday 11.40, I

In order to construct spatial polynomial curves endowed with useful algebraic structures, the Pythagorean condition for polynomials has been largely investigated. For this reason, the scientific research has dedicated a very broad activity in the study and analysis of PH curves and their applications. Recently, by adding a second Pythagorean condition, a particular subset of the spatial PH curves – called "double" Pythagorean-hodograph (DPH) curves – has been studied and identified. DPH curves encompass all polynomial helices which are characterized by further geometric features. Since the existence of a rational Frenet frame is equivalent to the double Pythagorean-hodograph structure, the introduction of DPH curves has allowed to characterize the conditions under which the Frenet frame has a rational dependence on the curve parameter. Nevertheless, an open research area is devoted to identify PH curves for which the rotation–minimizing frame is rational. In this talk, we present some recent results concerning the above mentioned topics.

Two Computational Advantages of Mu-Bases for the Analysis of Rational Planar Curves

Ron Goldman and Xiaohong Jia
Rice University

Friday 10.30, II

A μ-basis for a rational planar curve is a basis of lowest degree for the moving curve module – i.e. the syzygy module – of a rational parametrization for the curve. Over a dozen years ago, Tom Sederberg first observed that due to their low degree μ-bases provide a computational advantage over classical techniques for the implicitization of rational planar curves. Here we shall show that μ-bases also provide a more efficient approach than classical methods for the computation of the singularities of rational planar curves.

Automated Generation of Finite Element Meshes Suitable for Floodplain Modelling

Andrew Goodwin
Umwelt (Australia) Pty Limited

Saturday 10.10, II

Modern techniques such as Airborne Laser Scanning (ALS) provide dense point clouds that can be used to describe a topographical surface. A recent application of ALS is to flood modelling. One of the challenges faced when modelling flooding is generating a mesh that contains enough detail to accurately represent important surface features whilst remaining computationally viable. In order to meet these challenges, a number of methods have been developed that facilitate the generation and validation of finite element meshes suitable for floodplain modelling.

This paper describes a case study focusing on a longwall mining operation in the Hunter Valley of New South Wales, Australia. In the associated program of work, finite element meshes representing floodplains were developed by simplifying airborne laser data point clouds. The required level of detail present in the finite element mesh was achieved by manipulating a surface generated using quadric error metrics. Further steps were taken to ensure that the hydrodynamically significant features of the landform were retained. Several versions of the mesh were developed to represent various subsidence scenarios, allowing different stages of the longwall mining process to be investigated. In the overall project, particular emphasis was placed on linking visualisation techniques to the underlying model and the hydrodynamic solutions.

The general methodology described in the paper has applications in many other areas of environmental modelling including noise, dust, drainage and archaeology.

Computing n-variate orthogonal discrete wavelet transforms on the GPU

Lubomir T. Dechevsky and **Joakim Gundersen**
Narvik University College

Tuesday 9.50, II

In [1,2] we studied an algorithm for isometric mapping between smooth n-variate m-dimensional vector fields and fractal curves and surfaces, by using orthonormal wavelet bases. This algorithm matched only the orthonormal bases scaling functions (the "V-spaces" of multiresolution analysis). In the present communication we shall consider a new algorithm which matches the orthonormal bases of (mother) wavelets (the "W-spaces" of multiresolution analysis). In combination with the algorithm for "the V-spaces" from [1], [2], the new algorithm provides the opportunity to compute multidimensional orthogonal discrete wavelet transform in two ways – the "classical" way for computing multidimensional wavelet transforms, and by using a commutative diagram of mappings of the bases, resulting in an equivalent computation on the GPU. The orthonormality of the wavelet bases ensures that the direct and inverse transformations of the basis are mutually adjoint (transposed in the case of real entries) orthogonal matrices, which eases the computations of matrix inverses in the algorithm.

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[2] L. T. Dechevsky, J. Gundersen and A. R. Kristoffersen. Wavelet-based isometric conversion between dimension and resolution and some of its applications. In: Proceedings of SPIE: Wavelet applications in industrial processing V, 2007, Boston, Massachusetts, USA, vol. 6763, 2007

Generalized Voronoi Diagrams in Urban Planning

Hans Hagen and Inga Scheler
TU Kaiserslautern

Friday 17.00, I

Nowadays, every application area (like biomedical visualization or soil science) has to deal with large amount of data which needs to be managed. In the application area of urban planning, several specialized systems exist. These commonly used systems are only suitable to explain and illustrate the planning process. There is a lack of goal oriented tools for interpretation and visual presentation of the mostly unstructured data. Here we present our clustering method using generalized area Voronoi diagrams realized in our tool IKone, tailor made to support the process of redevelopment of military conversion areas. First, we identify and describe the determining indicators as well as multiple actors. Additionally, based on the specific character of the parameters we have to extract the influence of the indicator to the entire area. Subsequently we arrange the parameters according to the different views given by the actors. We define the different views by an individual weighting of location factors for the predefined usage. Thereon we identify our own specified metric which is able to handle the variety of indicators as well as the actors. Combining a clustering-process with a selective visualization technique provides a powerful tool for interpretation. Our goal is to superpose the clustering and visualization process with the geographic position of the conversion area. The restructured data gives the basis for the simplification and structuring of the planning process for the conversion of land formerly utilized by the military. Based on the tessellation we present the results of the analysis with the help of an overlay-technique. To allow a deeper insight of the result, the fundamental input data is represented by a multidimensional visualization technique.

Convergence of Subdivision Schemes with Hoelder Continuous Masks and its Applications

Bin Han

Saturday 18.00, I

Many masks in applications are not 2π-periodic trigonometric polynomials. For example, the masks for rational splines are $2^{-m}(1+e^{-i\xi})^m$ with a positive real number m. Masks for Butterworth filters in engineering take the form $p(\xi)/q(\xi)$ with 2π-periodic trigonometric polynomials p and q. Hölder continuous masks also unavoidably appear in the study of compactly supported Riesz wavelet bases which are of interest in wavelet-based numerical algorithms for PDEs. In this talk, we shall completely characterize the convergence of subdivision schemes and cascade algorithms in weighted L_2 spaces with Hölder continuous masks. Based on this result, we are able to settle several important problems in wavelet analysis. For example, we show that if a refinable function ϕ in L_2 has an exponentially decaying mask, then ϕ must have exponential decay too. This settles a conjecture by Daubechies. Our result also leads to a complete characterization of Riesz wavelet bases with Hölder continuous masks. This talk is based on [B. Han, Refinable functions and cascade algorithms in weighted spaces with Holder continuous masks, SIAM J. Math. Anal. **40** (2008), Issue 1, 70–102.]

Biharmonic Spline Approximation from Simple Layer Potentials

Thomas Hangelbroek
Texas A and M University

Thursday 11.40, II

This talk deals with two important mathematical problems arising in radial basis function (RBF) approximation. The first concerns finding optimal error estimates for correct classes of functions. Existing error estimates for RBF approximation are very effective when the error is measured in L_2. However, when the error is measured in other norms, the best error estimates often give suboptimal convergence rates, or provide optimal rates for excessively small classes of functions. The second problem concerns the search for approximations that effectively treat the boundary of a domain: it is well known that the error in RBF approximation is non-uniform over the underlying domain and is particularly larger in a small neighborhood of the domain's boundary.

Focusing on approximations generated by translates of the fundamental solution of the 2D biharmonic equation, we introduce a new type of approximation scheme - an extension of one recently developed for the unit disk - to treat functions defined on very general domains in $\mathbb{R}^2$. We show that the L_p-approximation order for such a scheme is $2 + 1/p$, which matches a known upper bound and consequently is the best possible order. Moreover, this rate holds for smoothness classes that are roughly as large as the theory allows. We also show that the (much better) boundary-free approximation order can be obtained for sets of centers with an appropriate density near the boundary, and that, by supplementing a given set of centers, this increased convergence rate can be achieved with little extra computational cost.

Interactive Texture Based Flow Visualization

Charles Hansen and Guo-Shi Li
Scientific Computing and Imaging Institute, University of Utah

Friday 18.00, I

Flow fields play an important role in a wide range of scientific, engineering, and medical disciplines. Due to the advancements in computing technologies and computational fluid dynamics (CFD), recently

we have seen a large number of flow datasets with ever increasing size and complexity from numerical fluid simulations. In order to obtain valuable information from these data, it is essential to devise effective computational flow visualization methods. Flow visualization methods can be highly useful to comprehend and analyze these data.The computational cost to generate such an image should not be overly expensive to increase the usefulness of a flow visualization method in a wide range of applications.

In the past few years, the texture advection approach has been the de facto solution for flow visualization in the research community. This approach can be used to realize dense texture visualization and dye advection, where the former is designed to depict instantaneous local features in the entire domain, and the later focuses on highlighting the spatial-temporal relationship between the injection site of the dye material and the rest of the domain. Presented as textures, the resulting visualization from these approaches is considered easy to understand at the cost of elevated computation cost. Since both approaches can be realized as a texture generation process, tremendous performance gains can be obtained by utilizing graphics hardware originally designed for rendering purposes. Due to the difference in design paradigm and hardware constraints, however, many methods proposed by previous research have been focused on performance issues while sacrificing the faithfulness of the resulting visualization.

To tackle this problem, in this talk I will present several accuracy-oriented texture-based flow visualization methods for two-dimensional unsteady flows, unsteady flows on surfaces, and dye advection. Issues regarding the accuracy and faithfulness of the visualization are rigorously treated with algorithmically and physically correct solutions. These schemes are also designed to leverage parallelism that can be accelerated by the current generation of graphics hardware to achieve interactive performance.

Interactive Visual Analysis of Timedependent Multivariate Data

Helwig Hauser
University of Bergen

Friday 17.30, I

The context of time-dependent multivariate data creates special challenges for interactive visual analysis, especially when large amounts of time series are given. We investigate and compare different approaches to realize analytical procedures for such datasets from different application fields (including sensor data analysis, automotive simulation, and medical perfusion analysis). One opportunity is to enable the interaction with large amount of curve representations [1]. Another approach is based no differential information [2] and a third approach integrates shape parameters and statistical analysis [3]. The individual strengths of the discussed approaches are documented by selected analysis examples.

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[2] Helwig Hauser: Interactive Visual Analysis – an Opportunity for Industrial Simulation. Invited paper in the Proc. of the 17th Conf. on Simulation and Visualization (SimVis), March 2-3, 2006
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Numerical Integration over Spherical Caps

Kerstin Hesse
University of Sussex, United Kingdom

Saturday 17.00, II

In this talk, we discuss numerical integration over spherical caps.

We explicitly construct tensor product rules for numerical integration over a spherical cap on S^2 that have positive weights and integrate polynomials up to a high degree n exactly. The rules have been implemented and tested and we show illustrations of the geometric distribution of the nodes as well as the performance of the rules for some test functions. The construction also works for S^d and the order $O(n^d)$ of the number of nodes is optimal. A slight modification of the construction yields also equal weight rules with $O(n^3)$ nodes with polynomial exactness of degree n for numerical integration over spherical caps on S^2.

Finally we discuss error estimates for such rules in a Sobolev space setting: The worst-case error of positive weight rules with polynomial degree of exactness n for numerical integration over spherical caps on S^d is of the order n^{-s} for functions in unit ball of the Sobolev space H^s, where $s > d/2$.

The construction of the rules and the analysis of their properties is joint work in progress with Rob Womersley. Local integration over subsets of the sphere with high polynomial degree of exactness has only recently attracted attention, and the present work is motivated by such recent attempts and by analogous results for numerical integration over the (whole) sphere.

Detecting and Preserving Sharp Features in Anisotropic Smoothing for Noised Mesh

Masatake Higashi, Masakazu Kobayashi and Tetsuo Oya
Toyota Technological Institute

Tuesday 9.50, I

We propose a smoothing method for noised meshes. We calculate fairness factors from first and second order discrete Laplacians at mesh points and obtain sharp features in the mesh by connecting edges which have large values of the factors at both the ends and by refining the edges as a graph. Then, we use these results for anisotropic smoothing and obtain a smoothed shape which preserves the sharp features included in the mesh. We demonstrate some examples which show effectiveness of the proposed method compared to other fairing methods such as diffusion of curvature flow and bilateral denoising.

CSG operations of arbitrary primitives with inclusion arithmetic and real-time ray tracing

Hans Hagen, Charles Hansen, **Younis Hijazi**, Andrew Kensler and Aaron Knoll
University of Kaiserslautern, IRTG 1131
SCI Institute, University of Utah
University of Kaiserslautern, IRTG 1131, Speaker
SCI Institute, University of Utah, IRTG 1131

Thursday 10.30, I

We present a new method for interactively ray tracing Constructive Solid Geometry (CSG) objects of arbitrary primitives represented as implicit functions. Whereas modeling globally with implicit surfaces suffers from a lack of control, implicits are well-suited for arbitrary primitives and can be combined through various operations. The conventional way to represent union and intersection with inclusion arithmetic is simply using min and max but other operations such as the product of two forms can be useful in modeling joints between multiple objects.

Typical primitives are objects of simple shape, e.g. cubes, cylinders, spheres, etc. Our method handles arbitrary primitives, e.g. superquadrics or non-algebraic implicits. We use subdivision and inclusion arithmetic (interval arithmetic and reduced affine arithmetic) to guarantee robustness and GPU ray tracing for fast and aesthetic rendering. Indeed, ray tracing parallelizes efficiently and trivially and thus takes advantage of the continuous increasing computational power of hardware (CPUs and GPUs); moreover it lends itself to multi-bounce effects, such as shadows and transparency, which help for the visualization of complicated objects. With our system, we are able to render multi-material CSG trees of implicits robustly, in interactive time and with good visual quality.

Simplification of FEM-models on multi-core processors and the Cell BE

Jon Hjelmervik and Jean-Claude Léon
Sintef
ENSHMG-INPG Laboratory G-SCOP

Monday 18.00, II

Preparing a CAD model for finite element analysis can be a time-consuming task, where mesh simplification plays an important role. It is important that the simplified model has the same mechanical properties as the original model, and that it is within a given error tolerance.

Most mesh simplification algorithms are either fully or partially sequential, and are therefore not suitable for architectures with high levels of parallelism. Furthermore, the use of processors such as GPUs of IBMs Cell BE requires algorithms to be adapted to benefit from their computational advantages. Here, we present an algorithm written for parallel processors, and its implementation for the Cell BE and multi-core CPUs.

The parametric four point scheme

Nira Dyn, Michael Floater and **Kai Hormann**
Tel Aviv University
University of Oslo
Clausthal University of Technology

Monday 14.10, II

Dubuc's interpolatory four-point scheme inserts a new point by fitting a cubic polynomial to neighbouring points over uniformly spaced parameter values. But it is well-known from cubic spline interpolation, that centripetal or chordal parameter values can give much better results than uniform ones for non-uniformly spaced data points. Therefore, we modify the four-point scheme and locally fit cubic polynomials with respect to centripetal or chordal parameterization of the data points to compute new data points. The resulting scheme is non-linear and data-dependent. We prove convergence of the two schemes and bound the distance between the limit curve and the initial control polygon. Numerical examples indicate that like for the classical four-point scheme the limit curves are C^1-continuous and that using centripetal parameter values usually gives the best curves.

Isogeometric Analysis: Progress and Challenges

Thomas J.R. Hughes
ICES, The University of Texas at Austin

Thursday 15.20

Geometry is the foundation of analysis yet modern methods of computational geometry have until recently had very little impact on computational mechanics. The reason may be that the Finite Element Method (FEM), as we know it today, was developed in the 1950s and 1960s, before the advent and widespread use of Computer Aided Design (CAD) programs, which occurred in the 1970s and 1980s. Many difficulties encountered with FEM emanate from its approximate, polynomial based geometry, such as, for example, mesh generation, mesh refinement, sliding contact, flows about aerodynamic shapes, buckling of thin shells, etc. It would seem that it is time to look at more powerful descriptions of geometry to provide a new basis for computational mechanics.

The purpose of this talk is to explore the new generation of computational mechanics procedures based on modern developments in computational geometry. The emphasis will be on Isogeometric Analysis in which basis functions generated from NURBS (Non-Uniform Rational B-Splines) and T-Splines are employed to construct an exact geometric model. For purposes of analysis, the basis is refined and/or its order elevated without changing the geometry or its parameterization. Analogues of finite element *h*- and *p*-refinement schemes are presented and a new, more efficient, higher-order concept, *k*-refinement, is described. Refinements are easily implemented and exact geometry is maintained at all levels without the necessity of subsequent communication with a CAD (Computer Aided Design) description.

In the context of structural mechanics, it is established that the basis functions are complete with respect to affine transformations, meaning that all rigid body motions and constant strain states are exactly represented. Standard patch tests are likewise satisfied. Numerical examples exhibit optimal rates of convergence for linear elasticity problems and convergence to thin elastic shell solutions. Extraordinary accuracy is noted for *k*-refinement in structural vibrations and wave propagation calculations. Surprising robustness is also noted in fluid mechanics problems. It is argued that Isogeometric Analysis is a viable alternative to standard, polynomial-based, finite element analysis and possesses many advantages. In particular, *k*-refinement seems to offer a unique combination of attributes, that is, robustness and accuracy, not possessed by classical *p*-methods, and is applicable to models requiring smoother basis functions, such as, thin bending elements, and strain-gradient and phase-field theories. A new modeling paradigm for patient-specific simulation of cardiovascular fluid-structure interaction is described, and a prcis of the status of current mathematical understanding is presented.

Stochastic resonance in quantized triangle meshes

Ioannis Ivrissimtzis
Durham University

Tuesday 10.10, I

We experiment with the effect of noise in the performance of a mesh compression algorithm which uses predictive encoding on quantized vertex coordinates. We notice that a small amount of added noise, even though it is expected to increase the entropy of the model, may lead to slightly smaller filesizes. We interpret this phenomenon with the signal theoretic concept of stochastic resonance. A small amount of added noise can slightly enhance regular patterns of the model's low frequencies, push them above the quantization threshold, and reduce the entropy of the model.

Interpolation by Planar Cubic G^2 Pythagorean-hodograph Spline Curves

Gašper Jaklič, Jernej Kozak, Marjeta Krajnc, Vito Vitrih and Emil Žagar
FMF, University of Ljubljana and PINT, University of Primorska, Slovenia
FMF and IMFM, University of Ljubljana, Slovenia
IMFM, University of Ljubljana, Slovenia
PINT, University of Primorska, Slovenia

Thursday 14.10, I

In this talk, the geometric interpolation of planar data points and two boundary tangent directions by a cubic G^2 Pythagorean-hodograph (PH) spline curve will be considered. It is well known that any cubic PH curve is a segment of a Tschirnhausen curve, which does not have any inflection points. Thus it is expected that such a curve can not be used to interpolate arbitrary chosen planar data points. But it will be shown that under some restrictions on data points such an interpolant exists. An algorithm for the construction of the spline will be presented and numerical examples given which indicate that the resulting spline curve

has nice shape properties. At the end some heuristic preprocessing methods for data points which do not guarantee the existence of the spline curve will be described.

Constrained T-spline Level Set Evolution

Bert Jüttler
Johannes Kepler University Linz

Friday 17.00, II

We study implicitly defined surfaces which are described as zero sets of T-spline functions. The use of T-splines leads to piecewise algebraic surfaces with local refinability. In order to reconstruct such surfaces from given data (e.g., unorganized point clouds), a dynamic framework has been developed, which combines ideas from image processing with classical techniques of surface fitting techniques.

In this talk we will mainly focus on the use of constraints. The constraints represent a priori knowledge about the shape of the object which is to be reconstructed. Several types of constraints will be discussed, such as range constraints, convexity and volume constraints. In addition, the elastic deformation energy will be used as a soft constraint on the evolution process. It leads to more realistic deformations of free-form objects.

The constraints can be be used to regularize the solutions, by avoiding problems with noisy and uncertain data. In addition, the effect of noise in the data can also be dealt with by adapting the evolution law which is used by the dynamic framework.

The talk is based on joint work with Martin Aigner, Robert Feichtinger, Matthias Fuchs, Otmar Scherzer and Huaiping Yang.

Adaptive isogeometric analysis by local h-refinement with T-Splines

Michael Dörfel, **Bert Jüttler** and Bernd Simeon
Technische Universität München
Johannes Kepler University, Linz, Austria

Thursday 17.00, I

Isogeometric analysis based on NURBS (Non-Uniform Rational B-Splines) as basis functions preserves the exact geometry but suffers from the drawback of a rectangular grid of control points in the parameter space, which renders a purely local refinement impossible. This paper demonstrates how this difficulty can be overcome by using T-splines instead. T-splines allow the introduction of so-called T-junctions, which are related to hanging nodes in the standard FEM. Obeying a few straightforward rules, rectangular patches in the parameter space of the T-splines can be subdivided and thus a local refinement becomes feasible while still preserving the exact geometry. Furthermore, it is shown how state-of-the-art a posteriori error estimation techniques can be combined with refinement by T-Splines. Numerical examples underline the potential of isogeometric analysis with T-splines and give hints for further developments.

Sharp Estimates of the Constants of Equivalence between Integral Moduli of Smoothness and K-Functionals in the Multivariate Case

Lubomir T. Dechevsky and **Ilya V. Kachkovskiy**
Narvik University College, Norway
Narvik University College, Norway; Departament of Physica, Saint-Petersburg State University, Russia

Thursday 14.30, II

This communication addresses the estimation of the equivalence constants between the Peetre K-functional $K_2(t^k, f; L_2(\mathbb{R}^n), \dot{W}_2^k(\mathbb{R}^n))$ and the integral modulus of smoothness $\omega_k(t, f)_{L_2(\mathbb{R}^n)}$. The constants $C_{k,p,n}$ and $D_{k,p,n}$, $k \in \mathbb{N}$, $1 \leq p \leq \infty$, are the minimal positive numbers, such that for every $f \in L_p(\mathbb{R}^n) + \dot{W}_p^k(\mathbb{R}^n)$ holds

$$D_{k,p,n}^{-1}\omega_k(t, f)_{L_p(\mathbb{R}^n)} \leq K_p(t^k, f; L_p(\mathbb{R}^n), \dot{W}_p^k(\mathbb{R}^n)) \leq C_{k,p,n}\omega_k(t, f)_{L_p(\mathbb{R}^n)}.$$

The previous known results about these constants (see [1]) are

$$C_{k,p,n} = O\left(\left(4k \max\left(\sqrt{n}, 1 + \log k\right)\right)^k\right),$$

$$D_{k,p,n} = O\left(\max\left(2^k, n^{k/2}\right)\right),\ k \to \infty,\ 1 \leq p \leq \infty.$$

In the present work we derive the following sharp estimates for $p = 2$:

$$\frac{1}{\sqrt{2}}\left(2\sin\frac{1}{2}\right)^{-k} \leq C_{k,2,n} \leq \sqrt{2}\left(2\sin\frac{1}{2}\right)^{-k}$$

and

$$2^k\sqrt{n} \leq D_{k,2,n} \leq 2^{k+1}\sqrt{n}.$$

This generalizes the result of the first author for the case $n = 1$ (see [2]).

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An algorithm for computing the curvature-sign domain of influence of Bezier control points

Panagiotis Kaklis
National Technical University of Athens

Friday 16.30, II

The below cited papers investigate the analytic structure of the domain, where a control point is free to move so that curvature (torsion) of a planar (spatial) parametric curve maintains constant sign over a user-specified subinterval of its parametric domain of definition. This

study resulted in a generic methodology for computing the domain of influence, assuming simply that the curve in question adopts the control-point paradigm with weight functions adequately differentiable.

In the proposed paper we develop an algorithm that materializes the afore-mentioned methodology for the curvature-sign of planar Bezier curves of degree n. The algorithm consists in evaluating the intersection of two finite families of convex sets, namely a family of cones and a family of rounded-vertex cones. The cardinality and characteris- tics of these sets can be derived from decomposing the envelope of a one-parameter family of lines into convex segments, which results in isolating the roots of a polynomial equation of degree at most $3(n-2)$.

The paper includes a combinatorial-, time- and volume-complexity analysis of the proposed algorithm and concludes with discussing its performance for a variety of artificial and industrial data.

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2. A.I. Ginnis, E.I. Karousos and P.D. Kaklis, Curve Fairing under Curvature and Tolerance Constraints, in Proceedings of the 6th AFA Conference on Curves and Surfaces, June 29 - July 5, 2006, Avignon, France, A. Cohen, T. Lyche, J.-L. Merrien, M.-L. Mazure and L.L. Schumaker (eds.)

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Weighted semiorthogonal spline wavelets and applications

Bert Jüttler and **Mario Kapl**
Institute of Applied Geometry, Johannes Kepler University Linz, Austria
Johann Radon Institute for Computational and Applied Mathematics (RICAM), Austria

Monday 14.10, I

We describe a non-standard tensor-product spline wavelet construction which is based on the one-dimensional wavelet transform. For this we construct weighted semiorthogonal spline wavelets. These are univariate spline wavelets which are semiorthogonal with respect to a weighted inner product. In our method the weighted inner product is automatically adapted to the given data and problem. That means, we design spline wavelets such that analysis provides an exact or approximate best approximation with respect to the norm induced by the weighted inner product. Finally, we consider different applications of this tensor-product spline wavelet construction and compare it with standard uniform spline wavelets. On the one hand we construct a multiresolution analysis of planar domains, on the other hand we use this tensor-product spline wavelet construction for optimal design, especially for structure recognition.

Finite multisided surface fillings

Kęstutis Karčiauskas
Vilnius University

Saturday 12.00, I

Existing first or second order smooth multisided surface constructions have high bidegree or shape problems. In the talk a method is presented based on:
(i) guide surfaces which represent designers intent;
(ii) G^1 and G^2 continuity.

The method produces fair G^2 fillings even of bidegree 5×5. More simple fair G^1 fillings of bidegrees 3×3, 4×4 are also described.

Subdivision Matrices of Normals and Jacobians for Surface and Volume Subdivision Schemes

Kiwamu Kase and **Hiroshi Kawaharada**
RIKEN

Friday 11.20, II

In this talk, we introduce subdivision matrices of normals and Jacobians for surface and volume subdivision schemes. These matrices give us normals or Jacobians at next step of subdivision.

In [KS06], we introduced the subdivision matrix of normals for stationary linear surface subdivision schemes. Using the matrix we can check the G^1-continuity of the subdivision scheme.

For stationary linear volume subdivision schemes, we introduce the subdivision matrices of normals and Jacobians similarly. Using these matrices we can derive an necessary and sufficient condition for G^1-continuity of the volume subdivision scheme.

As above, these matrices are powerful tools for volume subdivision analysis because of their existences for any stationary linear subdivision.

[KS06] Hiroshi Kawaharada and Kokichi Sugihara: Computation of Normals for Stationary Subdivision Surfaces, in the fourth International Conference on Geometric Modeling and Processing, pp. 585–594, Pittsburgh, 2006.

Vertex blending via surfaces with rational offsets

Rimvydas Krasauskas
Vilnius University

Thursday 17.30, II

A vertex blending is a surface that fills a hole surrounded by faces and edge blendings around the given vertex. We propose G^1 vertex blending surfaces with rational offsets of an n-sided angle with planar faces when edges are blended using right circular cylinders which might have different radii. We describe various kinds of such constructions in most details when $n = 3$:

- triangular patch - Bezier triangular or degenerated quadrangular surface;
- setback type solutions that combine canal surface and spherical patches;
- setback construction - a hexagonal toric patch.

Extensions of these methods for $n > 3$ cases and more general edge blendings will be discussed.

Generalized expo-rational B-splines for curves, surfaces, volume deformations and n-dimensional geometric modelling

B Bang, Lubomir T. Dechevsky, **A. R. Kristoffersen** and A. Lakså
Narvik University College

Friday 14.30, I

Abstract For the constructions consideres in items 1-4 of [1] we provide several model examples of expo-rational B-splines (true or generalized) in the case of curves (see item 1 in [1]). Next, we provide firstexplicit examples of the four constructions of ERBS for scattered sets on domains in $\mathbb{R}^n$, considered in item 2 of [1]. We then proceed to give first model examples of true and generalized ERBS biorthonormal multiwavlet bases, as discussed in item 3 of [1]. Finally, in connection with the ERBS-based finite element and finite volume methods (FEM and FVM), we study first examples of FEM and FVM for scattered interpolation, *based on ERBS with defects*. These ERBS-based constructions are simpler and more easy then the ones considered in item 2 of [1], but due to the high (possibly, transfinite) order of super convergence in all vertices, and special points on the edges, of a triangulation, they are excellent new tool for numerical analysis of boundry-value problems for PDEs over general domains in $\mathbb{R}^n$.

Reference

[1] L.T.Dechevsky. Generalized expo-rational B-splines. Communication at the 7-th Int. Conf. on Mathematical Methods for Curves and Surfaces, Tœnsberg ’2008, Norway. (To appear.)

Adaptive Directional Subdivision Schemes

Gitta Kutyniok and Tomas Sauer
Stanford University
University Giessen

Anisotropic structures play a fundamental role in a variety of areas such as image processing and hyperbolic PDE. Hence nowadays there is a pressing need to develop more flexible subdivision schemes which take directionality into account. In this talk, we will introduce subdivision schemes which provide a means to incorporate directionality into the data and thus the limit function. More precisely, we will develop a new type of non-stationary bivariate subdivision schemes, which allow to adapt the subdivision process depending on directionality constraints during its performance, and a complete characterization of those masks for which these adaptive directional subdivision schemes converge will be shown. We will then apply the introduced adaptive directional subdivision schemes to derive a fast decomposition associated with a sparse directional representation system for two dimensional data, where we focus on the recently introduced shearlet system. In fact, we will show that we obtain a flexible framework for deriving a shearlet multiresolution analysis with finitely supported filters, thereby leading to a fast shearlet decomposition.

A generalized B-spline matrix form of spline

Arne Lakså
Narvik University College

Thursday 10.10, II

Matrix forms of B-spline curves and surfaces have been considered in the work of several authors. Here we propose a new, more general matrix formulation and respective upgraded notation. In this matrix formulation it is possible to obtain the generation of the B-spline basis and the algorithms of deCasteljau and Cox-deBoor in a very lucid unified form, based on a single matrix formula. This matrix formula also provides an intuitively clear and straightforward unified approach to corner cutting, degree elevation, knot insertion, computing derivatives and integrals in matrix form, interpolation, and so on.

Interpolation of a bidirectional curve network by B-spline surfaces on criss-cross triangulations

Catterina Dagnino and **Paola Lamberti**
Department of Mathematics, University of Torino - Italy

Friday 10.10, I

This talk is concerned with the construction of quadratic C^1 B-spline surfaces on criss-cross triangulations, interpolating a network of B-spline curves satisfying assigned compatibility conditions. The main problem consists in finding a suitable surface representation such that the given curves are isoparametric curves. In case of arbitrary curves, we propose a scheme for their interpolation by B-spline curves, within a given tolerance.

Computing with implicit support function representation of hypersurfaces

Bohumír Bastl, **Miroslav Lávička** and Zbyněk Šír
University of West Bohemia, Pilsen, Czech Republic

Thursday 12.00, I

Recently, the support function representation of hypersurfaces has been applied on some chosen problems of CAGD. The support function $h(n)$ is a function defined on the sphere (or its suitable subset) and it is a certain kind of a dual representation. It was shown that this representation is, among others, very suitable for describing convolutions and offsets of hypersurfaces as these operations correspond to simple algebraic operations of the associated support functions. Nevertheless, given a parametric or implicit representation of a hypersurface it is not always possible to represent it via the support function (this is mainly due to the fact, that for each vector only one value of h is possible). We introduce a hypersurface representation which removes this main drawback of the support function representation; it is available for all algebraic hypersurfaces (given either implicitly, or parameterically). Moreover, it gives us the possibility to bring the theory of support functions to the method of classification of parameterized rational hypersurfaces with respect to their RC (Rational Convolutions) properties and their convolution degrees. We show how the implicit support function representation can be used for finding suitable reparameterizations of two given hypersurfaces to obtain a rational parameterization of their convolution hypersurface, if it exists. This algorithm is then applied on identification of PH curves/PN surfaces and computation appropriate PH/PN parameterizations (also of higher convolution degree).

Parallel Example-based Texture Synthesis for Surfaces

Sylvain Lefebvre
INRIA

Monday 17.00, II

Example based texture synthesis algorithms automatically generate a large image resembling a small input example. These approaches, first limited to flat pieces of texture material- wood, stones, bricks, cloth - have been extended to synthesize a given appearance directly on an object surface. This is an important tool in answering the growing demand for varied and detailed content in Computer Graphics applications.

Unfortunately, most of the existing approaches are considerably slow since they either require running a sequential algorithm or solving a global optimization problem. This prevents efficient implementation on massively parallel architectures, such as GPUs. As a consequence, surface appearances have to be pre-computed and stored for later display, generating a large amount of data.

This talk will first introduce the basic principles enabling fast, parallel texture synthesis on the GPU. We will then introduce our latest work on solid texture synthesis. Our algorithm removes the need for a 2D

parameterization by directly generating colors in a volume, but only around the surface. Our GPU implementation is fast enough to provide on-demand synthesis for appearing surfaces when interactively breaking or cutting objects.

The Adaptive Delaunay Triangulation - Properties and Proofs

Tom Bobach, **Burkhard Lehner** and Georg Umlauf
University of Kaiserslautern
TU Kaiserslautern

Saturday 10.30, II

Lately, a novel tessellation technique, called Adaptive Delaunay Tessellation (ADT), was introduced in the context of computational mechanics. The method starts out with the Delaunay triangulation of a domain and transforms it into a unique polygonal tessellation with certain desirable properties when used as the support for nodal integration schemes in the Finite Element Method.

So far, the thus defined tessellation has not received any in-depth investigation and its properties as claimed have not been proved. We give the outstanding proofs for the three main claims, uniqueness, connectedness, and coverage of the Voronoï tiles by adjacent ADT tiles.

Approximation on two-point homogeneous manifolds

Jeremy Levesley
University of Leicester

Monday 17.30, I

In this talk we will describe a realisation of two-point homogeneous manifolds. We will show how to compute the volume element on such spaces and produce the Jacobi polynomials which are the reproducing kernels for polynomial spaces on these manifolds. Such results are not new, but the proofs require some in depth understanding of Lie algebras and their homogeneous spaces. We will also give a covering result on such manifolds generalising the results of Reimer [1] for spheres. Such results can be used to bound the norms of hyperinterpolation operators on spheres, as given by Sloan and Wommersley [3], and Reimer[2]. We generalise such bounds for more general two-point spaces.

[1] M. Reimer, Spherical polynomial approximation: A survey, in Advances in Multivariate Approximation (W. Haussman, K. Jetter and M. Reimer eds.), 255-268.

[2] M. Reimer, Hyperinterpolation on the unit sphere at the minimal projection order, Journal of Approximation Theory 104, (2000) 272-286.

[3] I. H. Sloan and R. S. Womersley, Constructive polynomial approximation on the sphere, J. Approx. Theory 103 (2000), 91–98.

Curvature Continuity at Extraordinary Vertices

Charles Loop and Scott Schaefer
Microsoft Research
Department of Computer Science, Texas AM University

Monday 11.40, II

We present a second order smooth filling of an n-valent Catmull-Clark spline ring with n biseptic patches. We first derive correspondence maps that are used to define sets of constraints among the coefficients of adjacent patches. These constraints only depend on the valence n of the extraordinary vertex, enabling us to solve for data independent basis functions. Since our system of constraints is underdetermined, we find the solution that minimizes a quadratic energy functional. Our energy functional has the property that an absolute minimum of zero is achieved for a bicubic surface; meaning that when $n = 4$ we reproduce the regular bicubic B-spline case. In other cases, the resulting surfaces are curvature continuous and visual pleasing.

An Improved Error Bound for Gaussian Interpolation

Lin-Tian Luh

Monday 10.30, II

It's well known that there is a so-called exponential-type error bound for Gaussian interpolation which is the most powerful error bound hithertoo. It's of the form $|f(x) - s(x)| \leq c_1(c_2 d)^{\frac{c_3}{d}}\|f\|_h$ where f and s are the interpolated and interpolating functions respectively, c_1, c_2, c_3 are positive constants, d is the fill-distance which roughly speaking measures the spacing of the data points, and $\|f\|_h$ is the h-norm of f where h is the Gaussian function. The error bound is suitable for $x \in R^n, n \geq 1$, and gets small rapidly as $d \to 0$. The drawback is that the crucial constants c_2 and c_3 get worse rapidly as n increases in the sense $c_2 \to \infty$ and $c_3 \to 0$ as $n \to \infty$. In this paper we raise an error bound of the form $|f(x)-s(x)| \leq c_1'(c_2'd)^{\frac{c_3'}{d}}\sqrt{d}\|f\|_h$, where c_2' and c_3' are independent of the dimension n. Moreover, $c_2' << c_2, c_3 << c_3'$, and c_1' is only slightly different from c_1. What's important is that all constants c_1', c_2' and c_3' can be computed without slight difficulty.

A closed formulae for the separation of two ellipsoids involving only six polynomials

Laureano Gonzalez–Vega and **Esmeralda Mainar**
Universidad de Cantabria

Friday 9.50, II

By using several tools from Real Algebraic Geometry and Computer Algebra (mainly Sturm–Habicht sequences), a new characterization for the separation of two ellipsoids in three–dimensional Euclidean space is introduced. This condition is characterized by a set of equalities and inequalities involving only six polynomials and depending polynomially on the entrees of the matrices defining the two considered ellipsoids. This formula does not require in advance the computation (or knowledge) of the intersection points between them.

From the computational point of view this characterization is very well adapted for treating the case where the two ellipsoids depend on one or several parameters (what includes the important case of analyzing the interference between two moving ellipsoids).

Extracting a Shape Descriptor for 3D Models by means of a Rotation Variant Similarity Measure

Michael Martinek, Roberto Grosso and Günther Greiner
Universität Erlangen

Friday 12.00, I

The ability to extract spatial features from 3D objects is essential for tasks like shape matching and object classification. However, designing a feature vector to be invariant with respect to rotation, translation and scaling is a challenging task and is often solved by normalization techniques such as PCA, which can give rise to poor object alignment. On the other hand, a similarity measure for 3D objects which is variant under rotation is much easier to obtain but not useful for the majority of shape analyzing processes. In this paper, we introduce a novel method to extract a robust feature vector on the basis of a rotation-dependent similarity measure. Such a measure provides the correlation between two objects with respect to the space of rotations SO(3). The core idea of our algorithm is to apply this measure to the object itself in order to obtain a rotational autocorrelation. We determine significant points in the SO(3) which are descriptive for the underlying geometry and sample the similarity function along the axes formed by these points and the origin. The feature vector, defined to be the respective function plots, is invariant with respect to rigid-body transformations and discriminating for different object classes. It can not only be used to characterize an object with respect to rotational symmetry but also to define a distance between 3D models. Since the features can be entirely pre-computed, our method is also perfectly suitable to perform similarity searches in large 3D databases.

A greedy algorithm for adaptive hierarchical anisotropic triangulations

Albert Cohen and **Jean-Marie Mirebeau**
University Paris 6

Tuesday 10.50, II

A simple greedy algorithm for the generation of data-adapted triangulations is proposed and studied. Given a function f of two variables, the algorithm produces a hierarchy of triangulations ${}_N$ and approximations f_N which are piecewise affine on ${}_N$. The refinement procedure consists in bisecting a triangle in a direction which is chosen so to minimize the approximation error in some prescribed norm between f and f_N. We study the approximation error in the L^p norm when the algorithm is applied to C^2 functions. In particular, it is proved that the triangles tend to adopt an optimal aspect ratio (which is dictated by the local Hessian of f) as the algorithm progresses. Numerical tests performed on functions with analytic expressions or on numerical images illustrate the approximation properties of the algorithm.

Fractal approximation of functions almost everywhere and in spaces L_p $(0 < p < 1)$

Dmytro Mitin and Mykola Nazarenko
Department of Mathematical Analysis, Faculty of Mechanics and Mathematics,
Kyiv Taras Shevchenko National University

Sufficient conditions are found for fractal transform operator to be eventually contractive [1] in a subspace of weak metric space L_p, $0 < p < 1$. For this correspondent metric fixed point theorem [2] generalizing Banach contraction principle is used. Also limit behavior of fractal operator iteration sequence [3] in the sense of pointwise and almost everywhere convergences is considered. Some estimates for fractal approximation error are proved.

Applications to fractal image compression are proposed.

References

[1] D. Mitin, M. Nazarenko, *Fractal approximation of functions in some metric spaces and lossy image compression problem*, 6th International conference "Curves and Surfaces" (Avignon, France, June 29 – July 5, 2006): Résumés, p. 45.

[2] J. Jachymski, J. Matkowski, T. Świątkowski, *Nonlinear contactions on semimetric spaces*, J. of applied analysis, 1995, vol. 1, no. 2, p. 125–134.

[3] B. Bielefeld, Y. Fisher, *A convergence model*, Fractal image compression: Theory and application, ed. by Y. Fisher, New York, Springer, 1995, p. 215–228.

Multiresolution analysis for minimal C^r-surfaces on Powell-Sabin type meshes

M.A. Fortes, P. Gonzalez, **M.J. Moncayo** and M. Pasadas
Departamento de Matematica Aplicada, Universidad de Granada
Departamento de Matematica Aplicada y Estadistica. Universidad Politecnica de Cartagena (UPCT)

Saturday 17.30, I

Multiresolution and subdivision schemes are successfully applied in a variety of engineering fields. Subdivision schemes are based on refinement rules which are applied on a starting set of discrete data to generate a new "denser" set. This work is intended to provide a multiresolution analysis scheme to obtain a sequence of C^r-surfaces on a polygonal domain. The surfaces approximate a Lagrangian data set and minimize a certain "energy functional" related to the fairness control of the surface. The corresponding decomposition and reconstruction formulas are given in the framework of lifting schemes. To this aim, a class of non separable scaling and wavelet functions in bidimensional domains are defined. Two applications of the developed theory are also analyzed. The first one concerns noise reduction while the second one deals with the localization of the domains where the energy of a given surface is maximally concentrated. The spatial localization of the energy is performed by the use of the detail coefficients associated to the multi-scale representation of the minimal energy surfaces. Finally, some numerical and graphical examples, for different test functions and resolution levels, are presented.

Implicit shape reconstruction using a variational approach

Elena Franchini, **Serena Morigi** and Fiorella Sgallari
Dept.of Math., University of Bologna
Dept. of Math., University of Bologna

Saturday 11.40, II

In this work we consider the problem of shape reconstruction from an unorganized data set which has many important applications in medical imaging, scientific computing, reverse engineering and geometric modelling. The reconstructed surface is obtained by continuously deforming an initial surface following the Partial Differential Equation (PDE)-based diffusion model derived by a minimal surface like variational formulation. The evolution is driven both by the distance from the data set and by the curvature analytically computed by it. The distance function is computed by implicit local interpolants defined in terms of radial basis functions. Space discretization of the PDE model is obtained by finite co-volume schemes and semi-implicit approach is used in time/scale. The use of a level set method for the numerical computation of the surface reconstruction allows us to handle complex geometry and even changing topology, without the need of user-interaction. Numerical examples demonstrate the ability of the proposed method to produce high quality reconstructions. Moreover, we show the effectiveness of the new approach to solve hole filling problems and Boolean operations between different data sets.

Computing the topology of algebraic curves and surfaces

Bernard Mourrain
GALAAD, INRIA

Thursday 18.00, II

Computing the topology of algebraic curves and surfaces appears in many geometric modeling problems, such as surface-surface intersection, self-intersection, arrangement computation problems ... It is a critical step in the analysis and approximation of (semi-)algebraic curves or surfaces, encountered in these geometric operations.

The classical approach for algebraic curves in the plane projects the problem onto a line, detects the value which are critical for this projection and lift points back on the curve at these critical values and in between. Information on the number of branches at these critical values or genericity condition tests on the number of critical points above a value of the projection have to be computed, in order to be able to perform correctly the combinatorial connection step of these algorithms. This approach has also been extended to curves and surfaces in 3D.

One difficulty of this type of methods appears when the input description of the geometric objects is given with some errors. Another difficulty is the treatement of singularities through the analysis of fibers at critical values of a projection in a fixed direction.

In the presentation, we will compare this approach with subdivision methods that exploit information on the boundary of regions instead of information at critical points. We will describe new methods for computing the topology of planar implicit curves, which only requires the isolation of extremal points. We will show how topological degree computation can help analysing the number of branches at singular points. Combining regularity criterion with subdivision strategies yields a complete algorithm for computing the topology of (singular) algebraic curves. Extension of this approach to curves and surfaces in 3D will be described. We will also mention how this approach extends naturraly to curves and surfaces arrangement computation. Experimentation with the algebraic-geometric modeler AXEL will shortly be demonstrated.

Hexagonal meshes as discrete minimal surfaces

Christian Mueller
Institut of Geometry, Graz University of Technology

Saturday 10.10, I

We give a report on our recent work on hexagonal meshes as objects of discrete differential geometry. Based on a recent theory of curvatures for parallel mesh pairs, we consider a discrete Christoffel transformation which maps meshes covering the unit sphere to discrete minimal surfaces. We express this transformation in terms of oriented mixed areas of parallel polygons, which leads to incidence-geometric characterizations of discrete minimal surfaces.

Continuity analysis of double insertion, non-uniform, stationary Subdivision Surfaces

Gerald Farin, Christoph Fuenfzig, Dianne Hansford, **Kerstin Mueller** and Georg Umlauf
Arizona State University
TU Kaiserslautern

Monday 12.00, II

Double insertion, non-uniform, stationary Subdivision Surfaces are developed from the refinement rules of bicubic NURBS surfaces. They can deal with arbitrary two-manifold topology, arbitrary knot intervals on the edges and incorporate Catmull-Clark and bicubic NURBS surfaces. Their set of rules includes refinement and limit point, limit normal rules, as well as special feature rules. We analyze the continuity of this new subdivision surface and explain in detail where the surface is C^2 or only C^1. The study is accompanied by a variety of surface examples made with our Autodesk Maya plugin.

A Newton Basis for Kernel Spaces

Stefan Mueller and Robert Schaback
Universitaet Goettingen, Germany

Thursday 14.10, II

This talk presents a strategy for overcoming the ill–conditioning of linear systems arising from radial basis function or kernel techniques.

To come up with a more useful basis, the strategy known from Newton's interpolation formula is adopted, using generalized divided differences and a recursively computable set of basis functions vanishing at increasingly many data points.

The resulting basis turns out to be orthogonal in the Hilbert space in which the kernel is reproducing, and under certain assumptions it is complete and allows convergent expansions of functions into series of interpolants. Some numerical examples show that the Newton basis is much more stable than the standard basis.

Subdivision schemes for ruled surfaces and canal surfaces

Boris Odehnal
Vienna University of Technology, Institute of Discrete Mathematics and Geometry

Friday 11.40, II

Subdivision schemes for curves and surfaces are well studied. Interpolatory schemes and approximating schemes are investigated and convergence analysis is done so far. Recently subdivision for data in arbitrary manifolds is defined in two different ways: The constructions which are originally done in affine spaces for vector space data can be generalized to so called geodesic subdivision. On the other hand subdivision in model spaces applied to vector space data can be combined with a projection to an embedded manifold.

Both types of modified subdivision can be used for geometric modeling. Their applications are not restricted to curve and surface design. They can also be used for the design of smooth rigid body motions interpolating or approximating given positions.

In the following we will focus mainly on the design of ruled surfaces and canal surfaces. Both ruled surfaces and canal surfaces appear as curves in appropriate model spaces. Therefore it is sufficient to apply subdivision schemes for curves. The case of ruled surfaces will be treated more intensively and at least three different approaches for subdividing ruled surfaces will be presented. The first method is a combination of subdvision and projection to a manifold being a point model for the set of lines in Euclidean three-space. The second method combines an ordinary subdivision scheme for curves with geodesic subdivision in the Euclidean unit sphere. Finally we show that geodesic subdivision within the group of Euclidean motions can also be used to refine ruled surfaces.

The case of canal surfaces is much easier to handle since we can use the so called cyclographic model space for the set of spheres in Euclidean three-space. The points in this affine model space represent spheres and we can apply

interpolatory and approximating schemes as well. There is no need for projection or geodesic subdivision.

All these techniques are justified by the fact that sufficiently fine models of ruled surfaces and canal surfaces are good enough for scientific visualization.

C^1 Blending of Wachspress Rational Patches

Hanuman Prasad Dikshit and **Aparajita Ojha**
School of Good Governance and Policy Analysis, Bhopal, India 462 011
PDPM Indian Institute of Information Technology Jabalpur, India 482 011

Friday 18.00, II

Wachspress basis functions over convex quadrilateral elements have been studied in [1] from the point of view of applications to problems in CAGD. Interesting mathematical properties such as non-negativity of higher degree basis functions, asymptotic convergence of resulting rational patches to tensor product patches, convex hull property, projective invariance have been presented in the paper. Nice iterative algorithms have also been provided for computational convenience. In subsequent papers [2]-[3], composite Wachspress surfaces with C^1- continuity and formula for subdivision have also been studied. In addition, conditions for general C^k continuity have been derived in [2].

Keeping in view the importance of pentagonal hole filling problems, recently we have defined a set of quadratic Wachspress basis functions over pentagonal domains [4]. These patches are potentially good candidates for boundary color interpolation and other surface modelling applications in CAGD. The present talk concerns with conditions for C^1 smoothness of composite patches made up of pentagonal patches and triangular/ rectangular patches.

References

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[2] H.P. Dikshit and A.Ojha, CAGD 19, 207–224 (2002).

[3] H. P. Dikshit and A.Ojha, CAGD 20, 395-399 (2003).

[4] N. Choubey, H.P. Dikshit and A. Ojha, Submitted for Proceedings of ICIAM07, Zurich, Switzerland, July 16-20, 2007.

Shape preserving Hermite interpolation by rational biquadratic splines

Sablonnière Paul
INSA de Rennes, France

Monday 12.00, I

We study Hermite interpolation by a C^1 biquadratic rational spline S on a non-uniform grid of a rectangular domain R. The restriction $S_{i,j}$ of S to each rectangular cell $R_{i,j}$ of the grid is a C^1 biquadratic rational spline composed of four biquadratic rational patches. The local rational spline $S_{i,j}$ depends on 16 parameters and on some positive weights which can be chosen for preserving shape properties of the data, such as bimonotonicity and biconvexity, i.e. monotonicity and convexity in the directions of coordinate axes. Given arbitrary data $(z_{i,j}, p_{i,j}, q_{i,j})$ at gridpoints (x_i, y_j), we show that it is always possible to construct a biquadratic rational spline S satisfying $S(x_i, y_j) = z_{i,j}, , \partial_x S(x_i, y_j) = p_{i,j}, , \partial_y S(x_i, y_j) = q_{i,j}$. Moreover, if the given partial derivatives are of one sign at the vertices of a cell, those of the interpolant will have the same sign in the cell (bimonotonicity). Similarly, if the univariate data on the edges of the cell are convex (i.e. come from a convex function), then the local interpolant will be biconvex in the cell. Of course, such an interpolant has the classical drawbacks of tensor-product schemes, in particular the fact that shape parameters depend on data along grid lines, not only on local data on cells. However, it has the advantage of being rather simple to define and to construct thanks to the good shape properties of its control polygon which reflect rather faithfully those of the underlying surface.

Compactly Supported Splines with Tension Properties on a Regular Triangulation

Paolo Costantini, **Francesca Pelosi** and Maria Lucia Sampoli
Dipartimento di Scienze Matematiche ed Informatiche, University of Siena

Friday 17.30, II

Piecewise continuous functions with tension properties are nowadays very popular and are used in several practical problems, ranging from free form design to shape preserving interpolation or approximation. The univariate cases and their tensor product counterparts are relatively simple and, in particular, B-spline like basis with tension properties have been obtained. The construction of piecewise bivariate functions on a triangulation is by far more complicate; however, some triangular macro-elements and triangular elements ([1]) with tension properties have been recently proposed and used in the construction of composite C^1 functions. The missing point is the construction of suitable compactly supported spline functions.
In this talk we present a first result in this direction. First, we define a class of variable degree polynomial triangular elements, where the independent degrees associated to each vertex of the triangular domain play the role of tension parameters. These elements are a simplified version of those described in [1] and tend to affine functions for large degrees. Then we show that for a regular (i.e. based on equilateral triangles) triangulation it is possible to construct composite triangular C^1 functions which are non-negative and compactly supported on an hexagonal domain. Moreover, they form a partition of unity and reproduce first degree polynomials.

[1] P. Costantini, F. Pelosi, M. L. Sampoli: *Triangular Surface Patches with Shape Constraints.* in "Curve and Surface Design: Avignon 2006", 123–132, Nashboro Press, Brentwood, TN, USA.

Rational envelopes of two-parameter families of spheres

Martin Peternell
University of Technology Vienna, Austria

Thursday 17.00, II

Two-dimensional surfaces in R^4 and their corresponding two-parameter families of spheres in R^3 are investigated. We prove that a rational surface in R^4 corresponds to a family of spheres in R^3 whose envelope surface admits rational parameterizations if and only if it is a two-dimensional subvariety of a rational isotropic hypersurface.

This construction enlightens the relation between these surfaces and so-called PN-surfaces in R^3, which denote those rational surfaces in R^3 whose offset surfaces admit rational parameterizations. This approach allows to provide explicit parameterizations of all such surfaces.

Rational ruled surfaces, quadratically parameterized surfaces, isotropic hypersurfaces passing through rational curves in R^4 and isotropic hypersurfaces passing through quadrics in R^3 are examples of such surfaces.

Finally we show that there exists a class of surfaces in R^4 generalizing surfaces with linear normal vector fields in R^3. These surfaces also generalize quadratically parameterized surfaces in R^4 and possess a variety of remarkable properties.

Recent Techniques and Algorithms for High(er)-Quality Shape Design and Surface Representation

Jorg Peters

Friday 15.20

The talk will explain and discuss spline-compatible approaches developed to improve surface shape where multiple primary surfaces meet; for example switching to polar layout and constructions using guide surfaces. The work is in parts joint with K. Karciauskas, U. Reif and A. Myles.

Generalized expo-rational B-splines and finite element methods for ODEs

Lubomir T. Dechevsky and **Olga L. Pichkaleva**
Narvik University College, Norway
Narvik University College and Faculty of Physics at the Saint-Petersburg State University, Russia

Friday 14.50, I

Our purpose is to consider first application of the approach proposed in item 4 of [1] for initial-value and boundary-value problems for linear ordinary differential equations with variable coefficients and right-hand side. The approximate solution is an Hermite interpolant based on expo-rational B-splines (ERBS) or their generalized version (Euler Beta-function B-splines, see [2]) over a possibly non-uniform knot-vector. The Hermite interpolation, together with the minimal support of the ERBS basis functions, lead to the following remarkable properties of the numerical solution:

(a) The issue of stability of the numerical solution is completely eliminated. The numerical solution is always stable for any knot-vector.

(b) The ERBS-based Hermite interpolant has transfinite order of accuracy.

(c) For an initial-value problems the stiffness matrix is triangular; for a boundary-value problems it is band-limited with the minimal possible width of the band. It can be shown that this bandwidth is smaller than in the case of polynomial B-splines, and this difference increases with the increase of the order of the differential equation.

(d) Modification and refining of a mesh lead to a very easy recomputation of the solution. Thus, multigrid methods with such approach are easy in implementation, cheap in computations, and very fast in convergence.

(e) The method works without any modifications also when the ODE degenerates (has variable order).

References:

[1] L. T. Dechevsky. Generalized expo-rational B-splines. Communication at the 7-th Int. Conf. of Mathematical Methods for Curves and Surfaces, Tnsberg2008, Norway. (To appear.)

[2] L. T. Dechevsky, A. Lakså, B. Bang. Introduction to generalized expo-rational B-splines. Applied Mathematics. Preprint 8470 No. 5/2007 ISSN 1504-4653, Narvik University College, Norway, 2007.

Polar varieties of real algebraic curves and surfaces

Ragni Piene
CMA/Department of Mathematics, University of Oslo

Friday 8.30

The theory of polars and polar varieties of a complex projective algebraic variety has played an important role in the quest for understanding and classifying projective

varieties. Their use in the definition of projective invariants is the very basis for the geometric approach to the theory of characteristic classes, such as Todd classes and Chern classes. Furthermore, the geometric nature of the polar varieties has lead to applications in various other directions: singularity theory, the determination of the geometry and topology of real affine varieties, algorithms for finding real solutions of polynomial equations, and to complexity questions.

In this talk, I will briefly survey the classical theory of polar varieties and explain various extensions and generalizations. I will give examples of some recent applications, due to work of Bank, Heintz, Mbakop, and Pardo, of Safey El Din and Schost, and of Bürgisser and Lotz. Finally, I will present joint work with H. Mork on polar varieties of real singular curves and surfaces.

An iterative algorithm with joint sparsity constraints for magnetic tomography

Gabriella Bretti and **Francesca Pitolli**
Dept. Me.Mo.Mat. - Università di Roma ”La Sapienza”

Thursday 12.00, II

Magnetic tomography aimed to spatially resolve vector-valued current distribution from its magnetic field measured in the outer space. Magnetic tomography has applications in several fields, such as medical imaging and nondestructive testing. However, the localization of current distribution is usually a highly ill-posed inverse problem which requires special regularization techniques.

We provide a fast and accurate adaptive algorithm for the resolution of current density under the assumption that its vector components possess a sparse expansion with respect to a preassigned refinable basis. Additionally, different components may also exhibit common sparsity patterns.

We model magnetic tomography as an inverse problem with joint sparsity constraints, promoting coupling of non-vanishing components. The solutions of the inverse problem is obtained by iterative thresholded Landweber schemes. The resulting adaptive scheme is fast and robust. Some numerical tests are also included.

Scattered Data Fitting using extended B-Splines

Oleg Davydov, **Jennifer Prasiswa** and Ulrich Reif
University of Strathclyde
TU Darmstadt

Friday 10.30, I

Given scattered data (ξ_i, f_i) on a domain $\Omega \subset \mathbb{R}^d$, standard splines fitting techniques either yield shape artifacts near the boundary or require a delicate choice of weights for fairness functionals. In this talk, we present new methods based on extended B-splines which combine good shape properties with optimal error estimates, and avoid the use of artificial smoothing terms.

For problems of modest size a global least squares fit is suitable, while for large problems a two-stage method combining local approximations is favorable in order to reduce the computational expense. Furthermore locality allows data dependent coupling of splines, a concept that is in line with the usage of the extended B-spline space, where coupling is boundary dependent.

If the data $f_i = f(\xi_i)$ are sampled from a smooth function and are sufficiently dense, then the use of extended B-splines of degree n yields the following bound on the approximation error Δ and its derivatives:

$$\|D^\alpha \Delta\|_\infty \le ch^{n+1-|\alpha|} \max_{|\beta|=n+1} \|D^\beta f\|_\infty, \quad |\alpha| \le n.$$

Numerical experiments illustrate the potential of these methods and validate the error estimate.

A point-based Clenshaw-Curtis type algorithm for computing curve length

Michael Floater, Hans Z. Munthe-Kaas and **Atgeirr F. Rasmussen**
University of Oslo
University of Bergen
Sintef Applied Mathematics

Monday 10.50, I

We describe a high-precision point-based algorithm for computing the arc-length of a parametric curve. The method is based on Chebyshev polynomial expansion and using the FFT, and is similar to Clenshaw-Curtis quadrature.

Ray Casting Algebraic Surfaces using the Frustum Form

Martin Reimers and Johan Seland
CMA
SINTEF ICT

Thursday 10.50, I

We present methods for efficient ray-casting of algebraic surfaces of high degree. A key point of our approach is a polynomial form adapted to the view frustum which can be computed efficiently using interpolation or blossoming. This so called frustum form yields simple expressions for the the ray polynomials, allowing robust and efficient root-finding using Bézier and B-spline techniques. The algorithms can be implemented efficiently on graphics hardware, yielding interactive visualization for degrees up to 20.

Constructing good coefficient functionals for bivariate C^1 quadratic spline quasi-interpolants

Sara Remogna
Dipartimento di Matematica, Università di Torino

Friday 11.20, I

This talk deals with discrete quasi-interpolants based on C^1 quadratic box-splines on uniform criss-cross triangulations of a rectangular domain. The main problem consists in finding good (if not best) coefficient functionals, associated with boundary box-splines, giving both an optimal approximation order and a small infinity norm of the operator. Moreover, we want that these functionals only involve data points inside the domain. They are obtained either by minimizing an upper bound of their infinity norm w.r.t. a finite number of free parameters, or by inducing superconvergence of the operator at some specific points laying near or on the boundary.

Sampling Inequalities and Applications

Christian Rieger
University of Goettingen

Saturday 17.30, II

Sampling inequalities formalize the observation that a differentiable function cannot attain large values if its derivatives are bounded and if it is small on a sufficiently dense discrete set. Sampling inequalities can be applied to the difference of a function and its reconstruction to obtain convergence orders for very general recovery processes. In my talk, the case of infinitely smooth functions is investigated, in order to derive error estimates with exponential convergence rates. I show a possibility to overcome the boundary effect, i.e., better estimates can be achieved by using more data points near the boundary. As an application of sampling inequalities, I present explicit deterministic results concerning the worst case behaviour of support vector regression problems in Sobolev spaces. I show how to adjust regularization parameters to get best possible approximation orders. The results are illustrated by some numerical examples. This talk is based on joint work with Barbara Zwicknagl.

Non-uniform interpolatory subdivision designed from splines

Carolina Beccari, Giulio Casciola and **Lucia Romani**
Dept. of Mathematics, University of Bologna, Italy
Dept. of Mathematics and Applications, University of Milano-Bicocca, Italy

Monday 14.30, II

Non-uniform subdivision schemes are currently emerging as one of the most highlighted trends in modelling curves and surfaces.
They represent a fundamental step to make subdivision comparable to NURBS, and, especially in the context of interpolation, they are regarded as a promising solution to improve the quality of the limit shape.

In this work we show how a set of linear refinement rules handling unequal knot intervals can be naturally designed by upsampling from a class of non-uniform, interpolating, polynomial spline functions. As a consequence, spline-like quality interpolants are easily obtained, whenever a proper non-uniform parameterization is associated to the edges of the initial polyline.

The proposed non-uniform subdivision algorithm constitutes a key ingredient towards the definition of spline-like quality interpolatory surfaces over meshes of arbitrary topology.

Multivariate Chebyshev Polynomials and Applications

Brett Ryland
Universitetet i Bergen

Friday 10.50, II

We generalise univariate Chebyshev polynomials to multivariate Chebyshev polynomials and use them to rapidly approximate the gradient and integral of a multivariate function on a triangular surface patch. This is joint work with Hans Munthe–Kaas.

Support Function Representation of Surfaces for Geometric Computing

Bert Jüttler and **Maria Lucia Sampoli**
Johannes Kepler University at Linz, Austria
University of Siena, Italy

Saturday 14.50, I

The support function (SF) representation of surfaces is a classical tool in the field of convex geometry. Recently, its application to problems from Computer Aided Design has been studied. For instance, it can be shown that SF representation of surfaces is useful for analyzing curvatures and for computing convolution surfaces (including offset surfaces). Moreover it has been shown that odd rational support functions correspond to those rational surfaces which can be equipped with a linear field of normal vectors. These surfaces, called LN surfaces (Linear Normals) have the remarkable property of possessing rational offsets and convolutions. As shown recently, this class of surfaces includes non–developable quadratic triangular Bézier surface patches.

In this talk we present a method for approximating a given free-form surface by a quadratic triangular spline surface. This leads not only to an approximating surface, but at the same time to an approximate SF representation by a piecewise rational (possibly multi-valued) function on the sphere, which is defined over a partition consisting of curved spherical triangles. As an application, we show how to generate a curvature–dependent triangulation of the original surface. In addition, the computation of convolutions will be addressed. Another potential application is the direct computation of isophotes on the surface.

Tensor Product B-Spline Mesh Generation for Accurate Surface Visualizations in the NIST Digital Library of Mathematical Functions

Bonita Saunders and Qiming Wang
National Institute of Standards and Technology, Gaithersburg, MD, USA

Tuesday 10.30, I

The National Institute of Standards and Technology (NIST) is developing a web-based digital library of high level mathematical functions to replace the widely used National Bureau of Standards Handbook of Mathematical Functions. The NIST Digital Library of Mathematical Functions (DLMF) will include formulas, computation methods, references, and software links for over forty functions. Access will be free and the library will feature a state of the art mathematical equation search and dynamic interactive 3D visualizations.

We will discuss our current work on a tensor product B-spline mesh generation technique we developed to facilitate the visualization of function surfaces in the NIST DLMF. Using our algorithm, we have been able to design boundary/contour fitted grids that capture key function features such as zeros, poles, branch cuts and other singularities on irregular, discontinuous, and multiply connected function domains. Thus, our algorithm has allowed us to resolve many of the problems that often appear with commercial packages where standard plots are usually over rectangular Cartesian domains.

In addition to our mesh generation algorithm, we have created translators that convert our 3D data into formats, such as VRML (Virtual Reality Modeling Language) and X3D (Extensible 3D Graphics), which can be read by plugins designed for interactive web viewing. We have completed over two hundred visualizations for the NIST DLMF. See http://dlmf.nist.gov/Contents for a mockup version of the website with a sample chapter on the gamma function. Others will be added in the coming months.

Sampling and Stability

Christian Rieger and **Robert Schaback**
University of Göttingen

Thursday 8.45

The first part of this survey will be rather general and deal with linear discretization processes in Numerical Analysis. Two useful tools are described:

- *Sampling Inequalities* for analyzing errors,
- *Stability Inequalities* for analyzing stability.

To apply the former to the latter, a third tool is necessary:

- *Inverse Inequalities*.

These are introduced in general terms first, together with their use for proving convergence of certain numerical methods. Then their recent variations are surveyed, including special forms for work with kernel–based trial spaces and "weak" data. Applications cover

- Machine Learning,
- Meshless Methods for PDEs,
- Lebesgue constants

and are presented as far as time permits. This survey will be based on work of Stefano DeMarchi, Wally Madych, Stefan Müller, Fran Narcowich, Christian Rieger, Robert Schaback, Joe Ward, Holger Wendland, and Barbara Zwicknagl.

http://www.num.math.uni-goettingen.de/schaback/research/group.html

Scattered data approximation on $SO(3)$

Dominik Schmid
Helmholtz Zentrum München

Tuesday 10.30, II

The problem of approximating functions defined on the rotation group $SO(3)$ is of great importance in various applications. In most of these problems we have to deal with non-equispaced sampling points on $SO(3)$. In this talk, we briefly introduce two methods for recovering functions from the given scattered data on the rotation group. Firstly, the interpolation of the given data by translates of a positive definite basis function, and, secondly the approximation by finite expansions into Wigner-D functions, which constitute an orthogonal basis of $L^2(SO(3))$. Then we focus on the latter approach. A central role is played by the construction of a sequence of new convolution type operators for polynomial approximation on $SO(3)$. We present some nice approximation properties of these operators and show how they can be used in order to derive L^p-Marcinkiewicz-Zygmund inequalities, $1 \leq p \leq \infty$, for Wigner-D functions. The inequalities are based on scattered sites on $SO(3)$. Finally, we point out how these Marcinkiewicz-Zygmund inequalities can be used in order to answer various scattered data approximation problems on the rotation group.

Conformal Equivalence of Triangle Meshes

Ulrich Pinkall, **Peter Schroeder** and Boris Springborn
TU Berlin
California Institute of Technology

Tuesday 8.30

We present a new algorithm for conformal mesh parameterization. It is based on a precise notion of *discrete conformal equivalence* for triangle meshes which mimics the notion of conformal equivalence for smooth surfaces. The problem of finding a flat mesh that is discretely conformally equivalent to a given mesh can be solved efficiently by minimizing a convex energy function, whose Hessian turns out to be the well known $\cot$-Laplace operator. This method can also be used to map a surface mesh to a parameter domain which is flat except for isolated cone singularities, and we show how these can be placed automatically in order to reduce the distortion of the parameterization. We present the salient features of the theory and elaborate the algorithms with a number of examples.

Pointwise radial minimization: Hermite interpolation on arbitrary domains

Michael Floater and **Christian Schulz**
CMA / IFI, University of Oslo

Thursday 10.10, I

In this talk we propose a new kind of Hermite interpolation on arbitrary domains, matching derivative data of arbitrary order on the boundary. The basic idea stems from an interpretation of mean value interpolation as the pointwise minimization of a radial energy function involving first derivatives of linear polynomials. We generalize this and minimize over derivatives of polynomials of arbitrary odd degree. We have a closer look at the cubic case, which assumes first derivative boundary data and has a unique solution with cubic precision. Numerical examples strongly indicate that the solution interpolates the data for a wide variety of domain shapes and behaves nicely.

A Non–Uniform Hermite Spline Quasi–Interpolation Scheme

Francesca Mazzia and **Alessandra Sestini**
Dip. di Matematica, Universitá di Bari
Dip. di Matematica, Universitá di Firenze

Friday 11.40, I

Quasi–Interpolation (QI) based on spline functions is a well–known approach for efficiently producing accurate approximations. Its effectiveness is due to the local definition of the spline coefficients in the B–spline basis. Recently, several interesting discrete QI schemes have been proposed in the literature, all assuming that the input data are of Lagrange type. As an alternative, here we propose a discrete/differential spline QI scheme which uses the function values at the spline knots together with the corresponding derivative values. An important feature of this scheme is that it doesn't require a uniform knot distribution.

The numerical results show that the use of the derivative values allows us to obtain very accurate approximations, even when "difficult" functions are approximated. Furthermore, it is clear that the possibility to choose a non–uniform knot distribution can be very useful to improve the approximation and it becomes a need when no a priori assumption on the data distribution can be made. For example, this is the case when a numerical approximation to the solution of a differential problem is automatically produced by a code implementing an adaptive mesh selection strategy. The application of this scheme to numerical quadrature will be also presented.

Practical methods of the geometry design and grid generation

Yuriy D. Shevelev
The Institute for Computer Aided Design of RAS

One of the basic problems of numerical modeling is creation of the most full model of geometry. In this paper the various methods of geometry design of the complete real configuration (/1- 4/) will be considered. Geometry design process involves defining an accurate numerical description by using the initial information. a) For fluid dynamics problems are convenient to set the surface analytically by algebraic methods. It is especially important to construct the model that is taking into account the main design parameters- baseline approximation. The geometries are presented as set of elements of geometry (for example, a fuselage, wings, etc.). Each element of a surface consists on compartments. A compartment may be expressed through geometrical parameters of cross section, for example, a wing: thickness, chord of section, curvature, etc. If the two-dimensional cross-section cuts of 3-D geometry select sections are known then a surface can obtain by stretching and extending the sheets of simplest surfaces (linear, spline, elliptical or minimal surface) between cross-sections. Thus analytical form of presentation gives an opportunity to define a surface by finite number of parameters. This approach is useful for optimization problems. Advantages of such techniques consist in that it can be used at all design levels. b) If the information is given by data then it is usual problem of interpolation. The traditional techniques of geometry design used: global and local interpolation methods, the splines interpolation, NURBS. The splines interpolation techniques are more universal. Surface representations used the cubic splines and supported a data structure to represent all geometric primitives with desirable properties as local control, convex shape preserving forms, etc. The splines interpolation techniques give us a minimum error for a special class of functions and interpolate derivatives. The interpolation is insensitive to the disturbances of the initial dates. The main ideas are implemented in the ACAD system (design system for aerodynamic purposes). An interactive design system ACAD is a complex of the programs and information facilities for a design and support of a geometric model of objects. c) In our practice we had been used algebraic, differential, conform mapping techniques of grid generation. Specific of studied problems dictates to use the different methods. The physical region is divided into sub-regions and within each sub-region a structured grid is generated. Structured block grid formed by a network of curvilinear coordinate lines such that a one-to-one mapping can be established between the physical and computational domains. The curvilinear grid points conform to the boundaries, surfaces, or both and therefore provide the most accurate way of specifying the boundary condition. The accuracy of computations depends on the mesh size of grid spacing in real space and the ability to control a physical mesh point's distribution. The grid adaptation is achieved by moving the grid points and refinement. The redistribution has been the favored approach with block-structured grids. The grid must takes into account geometrical and physical features of the flow field. A mesh must highly specialize for the particular problems (resolving the boundary and shear layers, shocks, wakes and so on). Size of mesh spacing near wall depends on Reynolds number. Just body fitted coordinate system can correctly resolved the viscous effect. d) A conformal mapping permits the sufficient preferences for solution of some concrete problems. It is well known that the 2-D conformal mapping does not generalize to 3-D case. From point of view of grid generation we dont need the fulfillment of all advantages of 2-D conformal mapping in 3-D case. We can consider a mapping that forms a subclass of the class of quasi-regular mappings. Then we studied a concept of quasi-potential 3-D transformations as an analogy of 2-D conformal transformations. The system of coordinate is forming by families of velocity potential surface and two streamline functions. The common solution is formally obtained. Perspective of using quasi-conformal mapping in common case will be considered. Finally some of the results applications will be displayed ([1-4]), particularly to prototypes of real configurations.

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Tetrahedral Meshes with Good Dihedral Angles

Bryan Klingner, Francois Labelle and **Jonathan Shewchuk**
University of California at Berkeley
Google

Monday 15.20

A central tool in scientific computing and computer animation is the finite element method, whose success depends on the quality of the meshes used to model the complicated underlying geometries. We develop two new methods for creating high-quality tetrahedral meshes: one with guaranteed good dihedral angles, and one that in practice produces far better dihedral angles than any prior method. The isosurface stuffing algorithm fills an isosurface with a uniformly sized tetrahedral mesh whose dihedral angles are bounded between $10.7°$ and $165°$. The algorithm is whip fast, numerically robust, and easy to implement because, like Marching Cubes, it generates tetrahedra from a small set of precomputed stencils. Our angle bounds are guaranteed by a computer-assisted proof. Our second contribution is a mesh improvement method that uses optimization-based smoothing, topological transformations, and vertex insertions and deletions to achieve extremely high quality tetrahedra.

Adaptive Fitting of C^∞ Surfaces to Dense Triangle Meshes

J. Gallier, D. Martínez, L. G. Nonato, **M. Siqueira**, L. Velho and D. Xu
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Instituto de Matemática Pura e Aplicada (IMPA), Brazil
Department of Computer Science, Bryn Mawr College, USA

Friday 10.50, I

A fundamental problem in Geometric Modeling is the one of constructing a smooth surface that interpolates or closely approximates the vertices of a given triangle mesh. Here, we introduce a new solution to this problem, which is catered to dealing with very dense triangle meshes, i.e., meshes with hundreds of thousands or even millions of vertices. Our solution has four main steps. First, a mesh simplification algorithm is applied to the dense input mesh, say M, to obtain a mesh M' whose vertices are a subset of the vertices of M. Second, we define a triangulation, T, on M. The vertices of T are the vertices of M', and the edges of T are geodesic curves on M. Each geodesic curve connects a pair of vertices of T that define a straight edge of M'. Third, we associate three Bézier patches with each "curved" triangle of T. The control points of each patch are determined by a least-squares based fitting using the vertices of M inside and around the associated patch. If the approximation error is greater than a pre-defined threshold, then T is locally refined and the fitting is carried out again for the new triangles. Fourth, we define a C^∞-continuous surface, S, by using a recently developed manifold-based surface construction. This construction combines the Bézier patches associated with the triangles of T using affine combinations. The size complexity of S is proportional to the total number of Bézier patches, which is three times the number of triangles of T. Thus, by carefully and adaptively simplifying the dense input mesh M, we can obtain a significantly more compact and yet accurate approximation to M. Furthermore, the resulting surface, S, is C^∞ everywhere, has fixed-sized local support for basis functions, is guaranteed to be in the convex hull of all control points, and its geometry can be locally controlled. All these features together make our solution more attractive than previous ones.

Hermite and Lagrangue Interpolation by Pythagorean Hodograph Curves

Zbyněk Šír
Charles University in Prague

Thursday 14.30, I

In our contribution we revisit some classical themes related to effective constructions of tool paths composed of segments of Pythagorean Hodograph (PH) curves. Using methods of algebraic geometry we extend the known classification of PH cubics to the case of PH quintics. We also present new interpolation results for PH cubics and quintics.

CAD and iso-geometric analysis

Tor Dokken and **Vibeke Skytt**
SINTEF

Thursday 18.00, I

If, in a finite elements computation, the solution space of the dependent variables is the same as the space describing the geometry, the mapping is said to be iso-parametric. In iso-geometric analysis the solution space used are spline spaces. The acceptance of iso-geometric analysis in industry will to a great extent be dependent on the ease of use and proper integration into product development processes. In STEP-type CAD-models volume objects are described by the outer shell and possible inner shells. A shell is described by a patchwork of surface pieces with boundaries matching within defined tolerances. The surface patches allowed are trimmed pieces of low degree algebraic surfaces and NonUniform Rational B-splines surfaces (NURBS). Iso-geometric volumes are represented by watertight structures of tri-variate parametric spline volumes, i.e., NURBS or T-splines based. Although the shells of STEP-type CAD-models and iso-geometric models at a first glance seem similar, a closer look shows that the iso-geometric shell is water tight, while the STEP-type shells allow small gaps. While the internal of a STEP-type volume is implicitly defined by the shells, the internal of the iso-geometric model is explicitly described by the trivariate splines. Consequently converting CAD-models to an iso-geometric description will both incorporate upgrading the CAD-model to be watertight, and impose an explicit internal structure aimed at the analysis at hand by building a tri-variate spline description. An important topic here is to handle trimmed surfaces. The talk will address this challenge and other geometric challenges related to the introduction of iso-geometric models in industrial product development

Circular spline approximation

Martin Aigner, Bert Jüttler and **Xinghua Song**
Johannes Kepler University, Inistitute of Applied Geometry, Linz, Austria
Johann Radon Institute for Computational and Applied Mathematics

Thursday 10.30, II

We consider piecewise circular curves in three–dimensional space. Compared to standard spline curves, circular spline curves have many advantages: the arc length can be computed exactly, and the offset surfaces (piecewise toroidal surface) can be represented by rational biquadratic surfaces. Moreover, the closest point of a given point in space can be found by solving quadratic equations, without any need for using iterative methods.

We propose a new method to approximate a given set of organized data points by space circular spline curve. An initial circular spline curve is generated at first. Then an evolution process is applied to the

curve. During the evolution process, the given points attract the corresponding closest points on the curve, and the circular spline curve converges to a stable limit shape. Our method does not need any tangent information and the evolution process ensures that the final curve contains as few the arc segments as possible. We proved the evolution process corresponds to

a Gauss-Newton-type method.

As a novel application of circular splines, we will show how to use them

to define edge detectors for implicitly defined surfaces.

Linear precision for parametric patches

Frank Sottile
Texas A & M University

Thursday 16.30, II

Linear precision is the ability of a patch to replicate affine functions. While classical patches possess linear precision, it is not clear which exotic patches (e.g. toric patches) have this property. In fact, every patch has a unique reparametrization having linear precision—but the resulting blending functions are not necessarily rational functions.

In this talk, I will give background and discuss work towards a classification of toric patches for which this reparametrization is given by rational functions. I will also explain how linear precision is related to maximum likelihood estimation in in algebraic statistics, and how to use iterative proportional fitting from statistics to compute patches. This is joint work with Luis Garcia, Kristian Ranestad, and Hans-Christian Graf von Bothmer.

From PS splines to QHPS splines

Paul Dierckx, **Hendrik Speleers** and Stefan Vandewalle
Katholieke Universiteit Leuven, Belgium

Monday 11.40, I

Powell-Sabin (PS) splines are C^1-continuous quadratic macro-elements defined on conforming triangulations. They can be represented in a compact normalized spline basis with a geometrically intuitive interpretation involving control triangles. These triangles can be used to interactively change the shape of a PS spline in a predictable way. QHPS splines are a hierarchical extension of PS splines. They are defined on a hierarchical triangulation obtained through (local) triadic refinement. For this spline space a compact normalized quasi-hierarchical basis can be constructed. Such a basis retains the advantages of the PS spline basis: the basis functions have a local support, they form a convex partition of unity, and control triangles can be defined. In addition, they admit local subdivision in a very natural way.

Anisotropic methods for restoring rotated and sheared rectangular shapes

Tanja Teuber
University of Mannheim

Monday 14.30, I

Methods for image restoration which recover edges and other important features are of fundamental importance in digital image processing. The aim of this talk is to present a novel technique for the restoration of images containing rotated and sheared rectangular shapes, which avoids round-off effects at vertices produced by known edge-preserving denoising techniques. The presented methods are based on anisotropic diffusion with special adaptations of the diffusion tensors and are numerically solved by finite difference methods. Moreover, some of these diffusion tensors can also be applied to model variational problems with anisotropic regularization terms. The corresponding functionals can be efficiently minimized by SOCP and their vertex-preserving properties are theoretically supported by the theory of Wulff shapes. In addition, numerical examples illustrate the good performance of our algorithms.
This is joint work with S. Setzer and G. Steidl (University of Mannheim).

Normal multilevel triangulations for geometric image compression

Adhemar Bultheel, Maarten Jansen and **Ward Van Aerschot**
Katholieke Universiteit Leuven, Belgium

Saturday 14.30, II

It is well known that image compression methods based on wavelet or fourier transforms have poor performance when it comes to dealing with 'geometrical' content. By geometrical content, we mean one-dimensional smooth manifolds, such as boundaries, contours, and ridges, *embedded* in a higher dimensional space (2D image) which define the location where the image is discontinuous.

Recursive partition methods, such as binary space partition (BSP) methods and wedgelets, capture geometrical content far more efficient than subband based methods. These methods partition images into several smaller segments such that the contours, present in the image, are approximated by the segment

boundaries.

In this talk, we present a novel approach, driven by surface regularity, called Normal Multilevel Triangulation (NMT), that performs segmentation and approximation simultaneously. The technique is strongly related to normal mesh methods originally developed for the compression of *smooth* two dimensional manifolds. All vertices of a normal mesh can be expressed by a single scalar value denoting the offset of the vertex in the direction normal to a coarser mesh.

While BSP and wedgelet methods are computational intensive in their pursuit for local optimal partitions, the proposed method does not exhaustively iterate through possible segment splits, but relies on the inherent property of vertex-to-contour attraction to align triangle edges tangential to the contour. In this way, only one set of parameters fixes both the image partition (geometrical content) and the piecewise linear approximation of the original image.

Newton-Cotes cubature rules over $(d+1)$-pencil lattices

Jernej Kozak and **Vito Vitrih**
FMF and IMFM, University of Ljubljana, Slovenia
PINT, University of Primorska, Slovenia

Saturday 16.30, II

In this talk, $(d+1)$-pencil lattices, which are well-known from the multivariate interpolation, will be used to extend the Newton-Cotes cubature rules to $(d+1)$-pencil lattices over simplices and simplicial partitions. The closed form of the cubature rules as well as the error term will be determined. Further, it will be shown that the additional freedom provided by $(d+1)$-pencil lattices, gives rise to an adaptive algorithm over simplicial partitions. The key point of the algorithm is the subdivision step that refines a $(d+1)$-pencil lattice over a simplex to its subsimplices.

Interpolation using scaled Gaussian Radial Basis functions

Marshall Walker

Department of Mathematics and Statistics, York University, Toronto, Canada

Saturday 14.50, II

A method for interpolating suitably triangulated data using scaled Gaussian radial basis functions is investigated. Generated surfaces are C^∞, possess local control, and implementation techniques are computationally trivial when compared with most radial basis methods.

In more detail, given a triangulation of a local region of the plane with vertices x_i together with data points (x_i, f_i) lying over the plane and given radial disks D_i centered at the vertices x_i, then assuming that $\bigcap_i D_i \neq$, scaled Gaussian functions ϕ_i are constructed with support confined to the disks D_i. An associated partition of unity ψ_i is constructed in the usual manner. For each disk D_i should vertices x_{i_j} lie in D_i a local function L_i is chosen to interpolate the data points (x_{i_j}, f_{i_j}). The desired interpolating function is then $S(x) = \sum_i L_i(x)\psi_i(x)$.

An implementation is presented for data lying over a rectangular grid with the local interpolating functions chosen to be bivariate Lagrange surfaces. For a specific application, given a parametric surface S described by $g : D \to \mathbb{R}^m$, a C^n normal vector field $n_{g(x)}$, and data points $(g(x_i, f_i))$ where $z_i - g(x_i)$ is normal to S, the described method is used to construct a C^n surface $f : D \to \mathbb{R}^m$ which interpolates given data and respects the geometry of the underlying surface S.

Learning Rates of Moving Least-square Regression in a Finite Dimensional Hilbert Space

Hongyan Wang, Daohong Xiang and Dingxuan Zhou

Monday 10.10, II

The Moving Least-square is one approximation method for interpolation and the numerical solution of differential equations. This paper applies the Moving Least-square method in learning theory for the regression problem by using the weight function. Here we provide an learning algorithm associated with the Moving Least-square loss and a finite dimensional Hilbert space of real valued functions on an "input" space X. The error analysis is the goal of this paper. As a consequence, we obtain the optimal rates for dealing with the general regression functions, comparing with the classical least-square method in learning theory. Of course the rates depend on the weight parameter and the capacity of the finite Hilbert space measured by covering numbers.

Interpolation and Compression of Image Data with Partial Differential Equations

Joachim Weickert
Faculty of Mathematics and Computer Science, Saarland University, Saarbruecken, Germany

Saturday 8.30

Interpolation of regularly sampled or scattered data is a frequent problem in many image processing and computer vision tasks. We present a PDE-based framework that generalises interpolation by splines and radial basis functions, and links them to approximation methods such as variational regularisation and anisotropic diffusion filtering.

For randomly chosen sparse data, experiments show the usefulness of an anisotropic nonlinear diffusion operator which originates from edge-preserving denoising. It leads to rotationally invariant interpolants that satisfy a maximum-minimum principle and outperform classical interpolation techniques such as thin plate splines. On the other hand, if one can select the data points freely, we observe that even a linear diffusion operator may perform well.

These findings are exploited for lossy image compression where only a few “useful” pixels are stored, and the missing data are reconstructed by diffusion-based interpolation. For the linear diffusion operator, results on optimal point selection are presented. In the anisotropic diffusion setting, a tree-based subdivision method is used to encode relevant pixels in a compact way. Our experiments demonstrate that PDE-based image compression may give better results than the JPEG standard, in particular if high compression rates are required.

Extensions to surface data will be presented in a later companion talk by Egil Bae.

Convergence and Smoothness Analysis of Nonlinear Stationary Subdivision Schemes in the Presence of Extaordinary Points

Andreas Weinmann
Institute of Geometry, Graz University of Technology

Monday 14.50, II

We report on our recent work on convergence and smoothness analysis of nonlinear subdivision schemes in the presence of extraordinary points. For a certain class of convergent stationary linear subdivision schemes we can show that the ‘nonlinear analogue’ converges for dense enough input data, if a proximity condition similar to that of Dyn and Wallner (2005) holds true. Furthermore, we obtain C^1 smoothness of the nonlinear limit function in the vincinity of an extraordinary point over Reif’s characteristic parametrisation.

Application of the dual Bernstein basis polynomials to the multi-degree reduction of Bézier curves with constraints

Stanislaw Lewanowicz and **Pawel Wozny**
Institute of Computer Science, University of Wroclaw, ul. Joliot-Curie 15, 50-383 Wroclaw, Poland

Thursday 10.50, II

We present a novel approach to the problem of multi-degree reduction of Bézier curves with constraints, using the dual constrained Bernstein basis polynomials, associated with the Jacobi scalar product. We give properties of these polynomials, including the recurrence relation, explicit orthogonal and Bézier representations, and the degree elevation formula. We introduce dual discrete Bernstein polynomials and show that they play an important role in the degree elevation process for the classical dual constrained Bernstein polynomials. This result plays a crucial role in the presented algorithm for multi-degree reduction of Bézier curves with constraints. An example is given.

Classification with Gaussians and Convex Loss

Daohong Xiang and Dingxuan Zhou

Saturday 12.00, II

This paper considers binary classification algorithms generated from Tikhonov regularization schemes associated with general convex loss functions and varying Gaussian kernels. Our main goal is to provide satisfactory estimates for the excess misclassification error. Allowing varying Gaussian kernels in the algorithms improves learning rates of the algorithm measured by the sample error and regularization error. The sample error is estimated by using a projection operator and a tight bound for the covering numbers of reproducing kernel Hilbert spaces generated by Gaussian kernels. We show how a Fourier analysis technique can be applied to get polynomial decays of the regularization error under a Sobolev smoothness condition. The convexity of the general loss function plays an very important role in our analysis.

Convergence of Increasingly Flat Radial Basis Interpolants to Polynomial Interpolants

Yeon Ju Lee, Gang Joon Yoon and **Jungho Yoon**
Department of Computer Sciences, University of Wisconsin, Madison
School of Mathematics, KIAS
Department of Mathematics, Ewha W. University

Thursday 14.50, II

In this paper, we study the convergence behavior of interpolants by smooth radial basis functions to polynomial interpolants in $\mathbf{R}^d$, as the radial basis functions are scaled to be increasingly flat. Larson and Fornberg conjectured a sufficient property for this convergence, and they also conjectured that Bessel radial functions do not satisfy this property. First, in the case of positive definite radial functions, we prove both conjectures by Larsson and Fornberg for the convergence of increasingly flat radial function interpolants. Next, we extend the results to the case of conditionally positive definite radial functions of order $m > 0$.

On the Logarithmic Curvature and Torsion Graphs

Ryo Fukuda, Takafumi Saito and **Norimasa Yoshida**
Nihon University
Tokyo University of Agriculture and Technology

Saturday 10.30, I

Many of aesthetic curves in the natural and artificial objects have been shown, by Harada et.al[1], to be curves whose logarithmic curvature graphs are approximated by straight lines. Based on the general formula[2] of log-aesthetic curves (formerly called aesthetic curves) derived by Miura, Yoshida and Saito identified the overall shapes of log-aesthetic curves and provided a method for generating a curve segment by three points like a quadratic Bézier curves[3].

This paper proposes to use logarithmic curvature graphs and logarithmic torsion graphs for analyzing the characteristics of (space) curve segments. First, logarithmic curvature graphs and logarithmic torsion graphs are defined to be drawn from free-from curves, such as Bézier or NURBS curves. We then present several characteristics of these graphs and point out that if logarithmic curvature (or torsion) graph is almost linear, the curvature (or torsion) is nearly represented by a simple function of arc length. Several examples of logarithmic curvature graphs and logarithmic torsion graphs drawn from planer and space Bézier curves are also shown.

References

[1] T. Harada, et al.: An aesthetic curves in the field of industrial design, Inn Proc. of IEEE Symposium on Visual Languages, pp.38-47, 1999.
[2] K. T. Miura, A general equation of aesthetic curves and its self-affinity, Computer-Adied Design and Applications, Vol.3, Nos.1-4, pp.457-464, 2006.
[3] N. Yoshida and T. Saito, Interactive Aesthetic Curve Segment, The Visual Computer (Proc. of Pacific Graphics), Vol. 22, No.9-11, pp.896-905, 2006.

Vector Field Subdivision

Thomas P. Y. Yu
Drexel University, Philadelphia, USA

Friday 12.00, II

In this talk I will describe a algorithm for modeling vector fields on (Loop or Catmull-Clark, say) subdivision surfaces, again using subdivision. The method is linear, is intrinsic, but is in a sense non-stationary. Being intrinsic, the scheme is also affine invariant. Using perturbation results from subdivision, we can show that the vector fields created by our scheme is C^2 away from extraordinary vertices. We also explore how to model vector field singularities of various types (sources, sinks, cycles, etc.) based on the proposed method.

If time allows, we wish to discuss the fundamental difference of our scheme with an interesting 1-form subdivision scheme developed at the Caltech Multiresolutuon Modeling group.

This is joint work with Tom Duchamp and Gang Xie.

Geometric Lagrange Interpolation by Planar Cubic Pythagorean-hodograph Curves

Gašper Jaklič, Marjeta Karjnc, Jernej Kozak, Vito Vitrih and **Emil Žagar**
FMF, University of Ljubljana and PINT, University of Primorska, Slovenia
IMFM, University of Ljubljana, Slovenia
FMF and IMFM, University of Ljubljana, Slovenia
PINT, University of Primorska, Slovenia

Thursday 14.50, I

Geometric Lagrange interpolation by planar cubic Pythagorean-hodograph (PH) curves will be considered. It will be shown that such an interpolatory curve can interpolate 4 data points provided that a data polygon, formed by the interpolation points, is convex, and satisfies an additional restriction on its angles. This gives rise to a conjecture that a PH curve of degree n can, under some natural restrictions on data points, interpolate up to $n+1$ points.

Scattered Data Reconstruction of Radon Data for Computer Tomography

Rick Beatson and **Wolfgang zu Castell**
University of Canterbury, New Zealand
Helmholtz Zentrum München, Germany

Monday 18.00, I

Kernel based methods have long shown to provide powerful interpolation and approximation schemes for scattered data. The classical approach uses radial basis functions to define interpolation schemes in $\mathbb{R}^d$. Analog constructions have been given for the sphere, while methods based on positive definite kernels for further domains have just been coming up lately.

We use the framework of abstract harmonic analysis to define suitable basis functions on the projective space $\mathbb{P}^d$. Since this is the natural space data for computer tomography is living in, we can apply the resulting schemes to solve missing data problems for scattered Radon data. The resulting reconstructions of CT images turn out to avoid artifacts resulting from other interpolation methods being used so far.

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