International Workshop on

New Trends in Applied Geometry

Villa Cagnola, Gazzada, Italy

February 12–17, 2012

Programme and Abstracts

Programme

	Monday	Tuesday	Wednesday	Thursday	Friday
07:30 – 09:00	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast
09:00 – 10:30	**M. Botsch** *S. Fröhlich* *D. Sieger*	**H. Prautzsch** *Q. Chen* *H. Speleers*	**P. Alliez** *J. Digne* *S. Giraudot*	**M. Floater** *G. Muntingh* *B. Siwek*	***J. Wallner*** *O. Ebner*
11:00 – 12:30	**K. Hormann** *T. Cashman* *S. Marras*	***C. Giannelli*** *S. Kleiss* *T. Nguyen* *T. Schulz*	**M. Wardetzky** *H. Schumacher* *C. Weischedel*	**N. Dyn** *P. Kozlov* *N. Sharon*	**J. Wallner** *F. Käferböck* *A. Vaxman*
13:00 – 14:30	Lunch	Lunch	Lunch	Lunch	Lunch
15:00 – 16:30	**U. Reif** *N. Lehmann* **T. Várady** *P. Salvi*	Free time	Excursion *(14:30 – 19:00)*	**J. Gravesen** *Nguyen M.* **M. Sabin** *J. Kosinka*	
17:00 – 19:00	Free time	Free time	Excursion *(14:30 – 19:00)*	Free time	
19:30 – 21:00	Dinner	Dinner	Dinner	Dinner	

Coffee and refreshments are available each day from 10:30 – 11:00 and 16:30 – 17:00.

The bar is open each day from 21:00 – 23:00.

Participants

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A continuous, editable representation for deforming mesh sequences with separate signals for time, pose and shape

Tom Cashman

It is increasingly popular to represent non-rigid motion using a deforming mesh sequence: a discrete sequence of frames, each of which is given as a mesh with a common graph structure. Such sequences have the flexibility to represent a wide range of mesh deformations used in practice, but they are also highly redundant, expensive to store, and difficult to edit in a time-coherent manner. We address these limitations with a continuous representation that extracts redundancy in three separate phases, leading to separate editable signals in time, pose and shape. The representation can be applied to any deforming mesh sequence, in contrast to previous domain-specific approaches. By modifying the three signal components, we demonstrate time-coherent editing operations such as local repetition of part of a sequence, frame rate conversion and deformation transfer. We also show that our representation makes it possible to design new deforming sequences simply by sketching a curve in a 2D pose space.

Smoothness analysis of some subdivision algorithms

Qi Chen

In the first part of the talk I review a C^1 analysis technique for subdivision schemes. This technique has been successfully applied to several infinite classes of quadrilateral and triangular subdivision schemes to analyze the C^1 continuity of the pertaining subdivision surfaces. It is now applied to certain generalizations of midpoint subdivision which include the Catmull-Clark algorithm.

In the second part of the talk I introduce a new G^k subdivision scheme which generates the limiting surface in the vicinity of an extraordinary point as the union of (quasi-)polynomial surfaces. I illustrate some resulting surfaces for $k = 2$ and compare them with subdivision surfaces generated by other G^2 schemes.

Surface reconstruction by an optimal transport approach

Julie Digne

An optimal transport approach to the surface reconstruction problem: We develop a new strategy for reconstructing 3D surfaces based on the optimal transport of sampled surface points to triangulation simplices. Guided by a transport distance measuring how good a mesh is relatively to the input point set, we are able to reconstruct anisotropic meshes, preserving both sharp features and shape borders, if any.

Nonlinear Markov semigroups and refinement schemes on metric spaces

Oliver Ebner

In this talk we settle the convergence question for multivariate barycentric subdivision schemes with nonnegative masks on complete metric spaces of nonpositive Alexandrov curvature, also known as Hadamard spaces. Using the concept of nonlinear conditional expectations due to K.-T. Sturm, we characterise these type of refinement algorithms as certain nonlinear Markov semigroups. This in turn leads to the fact that any such scheme converges on arbitrary Hadamard spaces if and only if it converges for real valued input data.

Volume mesh deformation for pose repair

Stefan Fröhlich

Example-driven approaches for shape deformation or physics-based simulations allow to achieve complex behaviors without complicated simulations, by learning the desired behavior from given example poses. Since the input examples are often defective or of insufficient quality, they have to be repaired in order to be used in an example-driven deformation framework.

In this talk we present an example-driven surface deformation method, demonstrate its problems due to low-quality input poses, and present initial ideas for pose repair. One based on a space-time vector field integration and another one based on a physics-inspired regularization of a volumetric tessellation of the input model.

Adaptive approximation with truncated hierarchical B-splines

Carlotta Giannelli

Surface fitting techniques based on hierarchical B-splines (HB-splines) allow an adaptive mesh refinement which can effectively handle the modeling of detailed local features. At each iteration step of the refinement procedure, the number of hierarchical levels is increased by one and refined B-splines with respect to the grid of this last level of detail may be added to the hierarchical basis. Even if the hierarchical basis is constructed according to a selection mechanism which suitably combines basis functions introduced at different levels, the number of overlapping HB-splines easily increases. In addition, hierarchical B-splines do not form a partition of unity. This motivates the construction and analysis of a normalized hierarchical basis – denoted as truncated hierarchical B-spline (THB-spline) basis – which further enhances the locality properties of the hierarchical model. The theoretical foundations for THB-splines are briefly introduced, and a selection of experimental results from their use in a classical least-squares fitting are presented. Compared to traditional HB-splines, THB-spline approximations exhibit sparser matrices and better numerical properties.

This is a joint work with Bert Jüttler and Hendrik Speleers.

Robust surface reconstruction from defect-laden data

Simon Giraudot

We aim at providing a reliable and robust framework to reconstruct smooth, closed surfaces from defect-laden point sets, possibly hampered with noise, outliers, non-uniform sampling and holes (missing data). Ultimately we seek for a method which does not require defining any prior knowledge about the defects, which suggests to research for a parameter-free approach. In this talk I will present a robust distance function based on optimal transportation between measures. I will then explain our current findings to detect the holes through a parameter-free integral formulation which robustly signs the said distance function. We would like to apply similar principles to devise a reconstruction method which would interpolate the input points on noise-free areas and robustly approximate them everywhere else.

Smooth surfaces from bilinear patches: discrete affine minimal surfaces

Florian Käferböck

With a quad mesh each face can be filled with a bilinear (Bézier) patch surface. We show that this process results in an overall smooth surface if the underlying mesh is a discrete affine minimal surface. We study which kinds of surfaces can be constructed with the help of a translational Lelieuvre normal mesh. For reasons of statics those surfaces where all bilinear patches have the same axis direction are of particular interest. Two methods are shown for user-friendly construction of all affine minimal surfaces of that kind.

IETI – Isogeometric Tearing and Interconnecting

Stefan Kleiss

Finite Element Tearing and Interconnecting (FETI) methods are a powerful approach to designing solvers for large-scale problems in computational mechanics. The numerical simulation problem is subdivided into a number of independent sub-problems, which are then coupled in appropriate ways. NURBS- (Non-Uniform Rational B-spline) based isogeometric analysis (IGA) applied to complex geometries requires to represent the computational domain as a collection of several NURBS geometries. Since there is a natural decomposition of the computational domain into several subdomains, NURBS-based IGA is particularly well suited for using FETI methods.

This paper proposes the new IsogEometric Tearing and Interconnecting (IETI) method, which combines the advanced solver design of FETI with the exact geometry representation of IGA. We describe the IETI framework for two classes of simple model problems (Poisson and linearized elasticity) and discuss the coupling of the subdomains along interfaces (both for matching interfaces and for interfaces with T-joints, i.e. hanging nodes). Special attention is paid to the construction of a suitable preconditioner for the iterative linear solver used for the interface problem. We report several computational experiments to demonstrate the performance of the proposed IETI method.

Extraordinary points in NURBS-compatible subdivision

Jiří Kosinka

In the talk we will deal with subdivision schemes based on arbitrary degree B-splines. We will focus on extraordinary points which exhibit various levels of complexity both in terms of knot multiplicity and valency.

Adaptive thinning of centers for approximation of large data set by radial functions

Pavel Koslov

Given a large set of points in $\mathbb{R}^n$ (called also centers) with function's values on it, the problem discussed in this talk is how to choose a small subset of centers such that it is possible to approximate with a predefined accuracy all the data values, by a linear combination of translates of a radial function to the centers. Our solution is based on adaptive thinning strategies, removing in a greedy way less significant points one by one so as to minimize an anticipated error. We derive anticipated errors of low complexity based on our observations that certain radial functions have the *"functionals consistency"* property, namely, that all L_p-norms, $1 \leq p < \infty$, and the maximum or the minimum functionals attain their minimums for the same translate of such a radial function. We develop also several other anticipated errors and test the thinning algorithms with the different anticipated errors on several examples. Our numerical tests demonstrate good performance of the proposed anticipated errors on continuous and piecewise continuous functions. We notice also from these tests that the proposed algorithms tend to select significant centers near minimums, maximums, and discontinuities of the approximated function and its first derivative.

This talk based on my M.Sc. thesis written under the supervision of Prof. Nira Dyn.

Modeling with ambient B-splines

Nicole Lehmann

We present a new approach to the approximation of functions on manifolds, which is based on so-called ambient B-splines. It combines full approximation power with simple implementation. The same idea is suitable for representing G^k-surfaces of arbitrary topology. Here, the concept can be refined by a bootstrapping strategy and adaptive hierarchical refinement. New formulas for computing curvature properties in this non-standard setup will also be given.

Perception and motion

Stefano Marras

Computer vision and geometry processing are often seen as two different and, in a certain sense, distant fields: the first one works on two-dimensional data, while the other needs three dimensional information. But are 2D and 3D data really disconnected?

Think about the human vision: each eye captures patterns of light, that are then used by the brain in order to reconstruct the perception of the observed scene. In a similar way, if the eye detects a variation in the patterns of light, we are able to understand that the scene is not static; therefore, we're able to perceive the *motion* of one or more object in the scene.

In this work, we'll show how the perception of the 2D motion can be used in order to solve two significant problems, both dealing with three-dimensional data. In the first part, we'll show how the so-called *optical flow*, representing the observed motion, can be used to estimate the alignment error of a set of digital cameras looking to the same object. In the second part, we'll see how the detected 2D motion of an object can be used to better understand its underlying geometric structure by means of detecting its *rigid parts* and the way they are connected.

A classification of the generalized principal lattices in space

Georg Muntingh

In multivariate polynomial interpolation theory, the properties of polynomial interpolants depend very much on the configuration of the interpolation points in space. An important class is made up by the generalized principal lattices, which form a corner stone in the classification of the meshes with simple Lagrange formula and can be viewed as a generalization of the triangular meshes.

While generalized principal lattices are defined by an abstract combinatorial definition, all generalized principal lattices in the projective plane arise from a real cubic curve in the dual projective plane. As all such curves are of arithmetic genus 1, one can ask the question: Which space curves of arithmetic genus 1 and degree 4 give rise to generalized principal lattices in dual projective space?

In this talk we show how complete intersections of quadric surfaces can be used to define generalized principal lattices in space.

Isogeometric analysis and shape optimization in electromagnetism

Nguyen Dang Manh *Anton Evgrafov* *Jens Gravesen*

Isogeometric analysis (IGA), a recently proposed numerical method for solving PDEs [1], has brought a new turn for FEM-based shape optimization due to its capability of representing a geometry exactly with relatively few design control points. Our main focus is to investigate the incorporation the methodology into shape optimization with a very tight connection to electromagnetic problems. In this talk, the following applications of the investigation will briefly be presented

- Prescribing first few eigenvalues of the Laplacian operators.
- Optimizing resonant micro-antennas for wireless energy transfer.
- Designing nano-antennas with strong field enhancement. (Collaborators: S. I. Bozhevolnyi, M. Willatzen, University of Southern Denmark).
- Optimization of magnetic density separators. (Collaborator: D. Lahaye, Delft University of Technology).

Remarkably, we have obtained antennas that perform one million times better than an earlier topology optimization result [2]. This shows a great potential of shape optimization using IGA in in electromagnetism.

[1] T.J.R. Hughes, J.A. Cottrell, Y. Bazilevs, *Isogeometric analysis: CAD, finite elements, NURBS, exact geometry and mesh refinement*, Comput. Methods Appl. Mech. Engrg., **194**, 2005.

[2] N. Aage, N. Mortensen, O. Sigmund. *Topology optimization of metallic devices for microwave applications*, International Journal for Numerical Methods in Engineering, **83**, 2010.

Boundary preserving volume parameterization

Thien Tuan Nguyen

We present an approach to build a bijective parameterization for a contractible domain in $\mathbb{R}^d$. The boundary of the domain is first decomposed and/or parameterized in order to make it topologically equivalent to the unit cube in $\mathbb{R}^d$. The map between the domain and the unit cube is constructed by successively designing its coordinate functions as a solution of an elliptic equation on the intersection of the previous coordinate functions' level sets. The computed map is proved to be bijective by the maximum principle and compatible to the boundary parameterization. The boundary-preserve spline representation for the domain is finally found by least squares fitting to the inverse map.

Multi-sided transfinite surface interpolation

Peter Salvi

One of the major problems in CAGD is to create mathematical representations for complex free-form objects composed of several smoothly connected surfaces. An intuitive solution is curvenet-based design, where designers directly define feature curves of the object, which are interpolated by multi-sided surfaces. A convenient representation for these models is based on transfinite surface interpolation. This talk will introduce two new schemes for transfinite surfaces: a true multi-sided generalization of the Coons patch, and another based on a natural combination of curved side interpolants. The two formulations are supported by new parameterizations that need to satisfy strict tangential constraints along the boundaries.

Decomposing envelopes of rational hypersurfaces

Tino Schulz

The envelope of a family of real, rational hypersurfaces is defined by an implicit equation in the parameter space. This equation can be decomposed into factors that are mapped to varieties of different dimension. The factorization can be found using solely gcd computations. The decomposition is used to derive some general results about envelopes, which also contribute to the analysis of self-intersections.

Convergence of discrete elastica

Henrik Schumacher

Discrete elastica are polygonal curves that minimize a certain discrete curvature energy. Due to their simplicity, discrete elastica are popular in e.g. computer graphics applications. Their approximation behavior has been observed numerically; however, a water-tight convergence proof has been missing so far. In fact, it is quite mysterious from the theoretical perspective, why discrete elastica exhibit such good approximation behavior. In this talk I will present such a convergence proof. To this end, I will introduce the notion of epigraphical convergence – a powerful tool from variational analysis.

Corner cutting and Bernstein operators adapted to positive definite matrices

Nir Sharon

We introduce the concept of admissible matrix mean and apply it for data consisting of symmetric positive definite matrices (SPD). We suggest to use this approach to adapt linear positive approximation methods for SPD-valued data. Specifically, we modify the corner cutting schemes and the Bernstein operators to the approximation of SPD-valued functions.

Two important cases of admissible means are treated in details, the exp-log and the geometric matrix means. We derive properties of the approximation schemes based on these means. The geometric mean is found to be superior in the sense of preserving more properties of the initial matrices, such as monotonicity.

This is a joint work with Uri Itay, under the supervision of Nira Dyn.

Space deformation for shape optimization

Daniel Sieger

Shape deformation techniques have been successfully employed to solve design optimization problems in engineering tasks, e.g., to optimize a car body with regards to a computational fluids simulation. In particular, space deformations are highly suitable for this application domain due to their ability to deform arbitrary geometries simultaneously as well as their robustness with regards to defects in the input data. In this talk several state-of-the-art space deformation techniques are introduced and investigated for their use in shape optimization problems. The methods are evaluated regarding several criteria such as computational performance, numerical robustness, adaptivity, accuracy and smoothness. Finally, challenging research questions that emerged during the investigation as well as directions for future work are discussed.

A simple Hermite interpolatory subdivision scheme

Bartłomiej Siwek

In this talk a simple Hermite interpolatory subdivision scheme will be presented. Problems with natural Hermite extension of the 4-point Dubuc's scheme will be discussed first, and a simplified version will be presented. The talk will continue with a more in-depth look at that particular version and conclude with a presentation of its most important properties: smoothness, approximation order and Hölder regularity.

Quasi-interpolation based on Powell-Sabin B-splines and their multivariate generalization

Hendrik Speleers

Quasi-interpolation is a general term covering the construction of efficient local approximants (with a low computational cost) to a given set of data or to a given function. In this talk, we present the construction of a family of quasi-interpolants based on bivariate Powell-Sabin splines. Powell-Sabin splines are quadratic splines defined on any triangulation with a particular refinement. These splines can be represented in terms of basis functions possessing all the nice properties of the classical univariate B-splines. The presented quasi-interpolants are constructed in a local way, they only require function values, and provide full approximation order. We also discuss how such a spline space, its corresponding basis, and quasi-interpolants can be generalized to the multivariate setting.

Reconstructing surfaces from planar slices

Amir Vaxman

We describe a simple algorithm to reconstruct the surface of smooth three-dimensional multilabeled objects from sampled planar cross-sections of arbitrary orientation. The algorithm has the unique ability to handle cross-sections in which regions are classified as being inside the object, outside the object, or unknown. This is achieved by constructing a scalar function on $\mathbb{R}^3$, whose zero set is the desired surface. The function is constructed independently inside every cell of the arrangement of the cross-section planes using transfinite interpolation techniques based on barycentric coordinates. These guarantee that the function is smooth, and its zero set interpolates the cross-sections. The algorithm is highly parallelizable and may be implemented as an incremental update as each new cross-section is introduced. This leads to an efficient online version, performed on a GPU, which is suitable for interactive medical applications.

Force diagrams and applications

Johannes Wallner

J. C. Maxwell initiated a theory of reciprocal force networks in 2D which developed into a systematic theory of reciprocal diagrams and convex polyhdra, with contributions by H. Crapo, W. Whitely and many others. The well known algorithm for computing Voronoi diagrams and Delaunay triangulations via convex hulls inscribed in a paraboloid is a special case of this. Recent research, especially by P. Block at ETH Zurich on "thrust network analysis" combines this theory with numerical methods in order to design self-supporting masonry structures. We investigate this topic from a geometric viewpoint and demonstrate interesting connections between differential geometry, discrete geometry, and geometric modeling.

TBA
Clarisse Weischedel