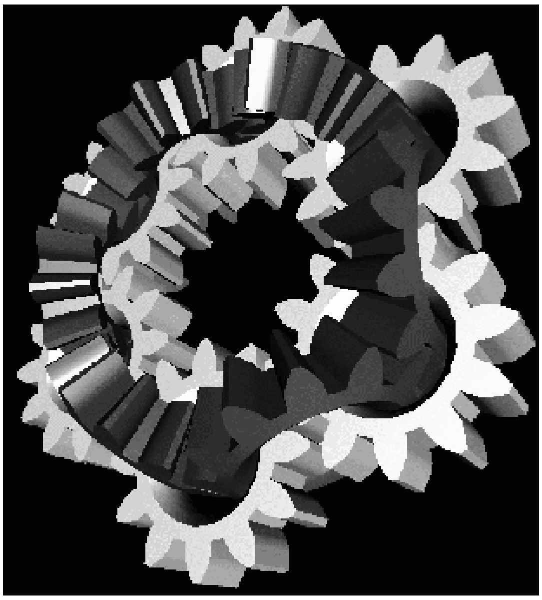
Book of Abstracts

IFIP & FSP International Workshop on Industrial Geometry:
Variational PDEs and Level Set Methods in Image Processing and
Shape Optimization 2010

April 07th – April 09th 2010, Obergurgl (Austria)



Organizers: Bert Jüttler and Otmar Scherzer
Local organizers: Thomas Fidler and Markus Grasmair

Biomedicine Needs New Applied Mathematics: A View from 2010.

Fred Leon Bookstein

Throughout the quantitative biomedical sciences, archives of instrumented data are expanding today far faster than our ability to distill them down into patterns, trends, or plausible interventions. Over the last half-century we have seen thrilling advances in morphometrics, chemometrics, finite-element analysis, biomedical imaging, multivariate calibration, microarray informatics, phylogenetic reconstruction, and many other technologies for the quantifications of "complex biological systems indirectly measured" that together sustain contemporary biomedical instrumentation. But there have been no corresponding advances in the tools of quantitative inference by which this information is turned into new insights into evolution, development, or disease. I argue that applied mathematicians should join with biomathematicians in pursuing these foundational issues in an interdisciplinary setting focusing on four interwoven themes: multiscale methods, multimodal distance/dissimilarity methods, multilocalization methods, and multimodel inference regarding all of these data sources via techniques of information theory. One central need is for tools dealing with the intrinsic variability of biological coordinate systems where we don't yet have sturdy heuristics that connect theorems to data representations. Another is for some way of coherently describing a predictable focus of a spatially extended phenomenon measured in one or more kinds of images at the same time.

Date: *07.04.2010*
Time: *09:00 – 09:45*

Metric on Radar Images Using the Monotone Rearrangement.

Jean–Paul Zolésio

We extend via tubes analysis the *Courant metric* developed in shape analysis to images. The geodesics in the space of images then turn out to be the solutions of certain incompressible Euler-like equations. We present some level set based solution algorithms for applications in radar imaging.

Date: *07.04.2010*
Time: *10:00 – 10:45*

Geodesics in the Space of Shapes.

Martin Rumpf

The talk will discuss ties between mechanics and the geometry on the space of shapes in imaging and vision. Thereby we consider shapes which are implicitly described as boundary contours of objects. The main focus will be on a physically sound model of geodesic paths in the space of shapes. Starting from a review of the literature in this field the general concept of shape space and the underlying challenges with respect to modeling, analysis, and computation will be examined. Based on these considerations a new model will be developed. In fact, a geodesic path will be defined as the family of shapes such that the total amount of viscous dissipation caused by an optimal transport of material along the path is minimized. To render the corresponding problem numerically feasible, a variational time discretization will be introduced, which is based on a sequence of pairwise matching problems and is designed to be strictly invariant with respect to rigid body motions. In the talk the limit for decreasing time step size will be investigated. It will be shown that the proposed model leads to the minimization of the actual geodesic length, where the Hessian of the pairwise matching energy reflects the chosen Riemannian metric on the shape space. Various examples for 2D and 3D shapes will allow a detailed discussion of the notion of geodesics and the challenge to link this notion to physics. The talk is based on joint work with Leah Bar, Guillermo Sapiro, and Benedikt Wirth.

Date: *07.04.2010*
Time: *11:15 – 12:00*

4D Embryogenesis Image Analysis using PDE Methods of Image Processing.

Karol Mikula

We discuss a set of methods for processing and analyzing long time series of 3D images representing the evolution of zebra-fish embryos. The images are obtained by in vivo scanning using a confocal microscope where one of the channels represents the cell nuclei and the other one the cell membranes. Our image processing chain consists of three steps: image filtering, object counting (cell center detection), and segmentation. The corresponding methods are based on the numerical solution of nonlinear PDEs, namely the geodesic mean curvature flow in level set formulation, flux-based level set center detection, and generalized subjective surface equation. All three models have a similar character and therefore can be solved using a common approach. We explain our semi-implicit time discretizations of level set type problems, their finite volume space discretization, and parallelization of the algorithms. The results concerning numerical analysis will be also discussed. Finally we show results of numerical experiments, validation of the methods, and various examples of applications processing the data representing an early developmental stage of a zebra-fish embryo.

Date: *07.04.2010*
Time: *14:00 – 14:45*

Adhesion Free Block Matching.

Antoni Buades

Block matching along epipolar lines is the core of most stereovision algorithms in geographic information systems. The usual distances between blocks are the sum of squared distances in the block (SSD) or the correlation. These distances suffer the adhesion (or fattening) effect, a defect by which the center of the block inherits the disparity of the more contrasted pixels in the block. This report shows that there is a simple and universal solution to this problem. It is enough to use an adaptive weight in the SSD. This weight is nothing but the square of the gradient of the first image in the epipolar direction. This magic adaptive weight yields a computed disparity that is the result of a convolution of the real disparity with a fixed kernel. The choice of the kernel is left to the user. Experiments on simulated and real pairs prove that the formula applies really, and eliminates surface bumps clearly due to the adhesion phenomenon.

Date: *07.04.2010*
Time: *15:00 – 15:45*

Computer Aided Geometric Design tools in Isogeometric Analysis.

Maria Lucia Sampoli

Isogeometric analysis is a new method for the analysis of problems governed by partial differential equations. The method has many features in common with Finite Element Methods (FEM), however, it is more geometrically based and takes inspiration from Computer Aided Design (CAD). This novel approach comes from the observation that in many PDE problems, such as solids, structures, and fluids, Finite Element Methods are based on crude approximations of the involved geometry, while the geometric approximation inherent in the mesh can lead to accuracy problems. Therefore in recent years an analysis framework based on functions capable of representing exact geometry was developed, giving rise to Isogeometric Analysis. The new method presented by Hughes et al. (2005) employs basis functions generated by NURBS (Non Uniform Rational B-Splines), a standard technology in CAD. This allows representing exactly the geometries of interest in engineering problems, which are usually described in terms of conic sections.

On the other hand many other CAGD techniques can be profitably used in order to describe accurately the domain where the PDE is defined as well as its solution. To this regard, in the CAGD community there is a huge amount of research on spaces of functions consisting of polynomials and either trigonometric or exponential or higher order polynomial functions (often called *generalized B-splines*) and it is well established how to construct B-spline like structures having sections in such spaces and possessing classical appealing features of polynomial B-splines (knot insertion, degree raising, etc.) and NURBS (exact representation of conic sections).

We focus our attention on function spaces possessing shape parameters that can be used to control the shape of the resulting objects. Generalized B-splines have revealed to be a very flexible tool in this context. They can be employed in different problems in order to satisfy specific requirements and constitute a valid alternative to NURBS. For instance in advection dominated flow phenomena, special generalized B-splines based on variable degree polynomials (the so called *variable degree splines*) have the distinguishing property of efficiently describing sharp variations without introducing extraneous oscillations. While in other problems generalized B-splines based on trigonometric functions give comparable results with respect to using NURBS, but avoiding the rational structure, the basilar operations of differentiation and integration (crucial aspect in the numerical treatment of PDE's) are much simpler and do not destroy the structure of the initial space as in the NURBS case.

In this talk the usage of generalized B-splines in Isogeometric Analysis is investigated and the results of joint works with Carla Manni and Francesca Pelosi are presented.

Date: *07.04.2010*
Time: *16:15 – 17:00*

Aerospace Applications of Isogeometric Analysis.

Thomas Grandine

For the better part of 20 years, Boeing has been making substantial use of B-splines as finite elements to solve a variety of engineering problems that frequently arise. B-spline finite elements are very appealing for many important reasons which include high-order accuracy, smoothness, and computational ease. They are also appealing because they naturally lead to problem solutions which interact beautifully with much existing computer-aided design (CAD) software. More recently, we have begun to examine isogeometric analysis as an extension to this basic idea with a view toward eliminating one of the more difficult bottlenecks that arise in performing design optimization. This talk will outline some of the progress that we have made in building practical tools to leverage this exciting new technology.

Date: *07.04.2010*
Time: *17:15 – 18:00*

Isogeometric Analysis: A New Paradigm for Engineering Design?

Régis Duvigneau

Automated design optimization procedures are now commonly used for complex engineering problems governed by partial differential equations, such as drag minimization in aerodynamics, weight reduction in structural mechanics, or maximization of energy transmitted by reflector antennas in electromagnetics. However, these procedures are often cumbersome, since they are achieved by coupling existing sophisticated numerical tools originating from Computer Aided Design (CAD), optimization (descent or evolutionary methods), simulation (finite-element, finite-volume), grid generation (structured or unstructured), etc. Moreover, these tools are based on different geometrical representations, ranging form NURBS (Non-Uniform Rational B-Splines) used in CAD, surface or volume grids used by physical solvers, to ad-hoc design parametrizations (angles, lengths, volumes, etc.) often used in optimization. Hence, several geometrical transformations are required in practice to couple these tools, which could have severe consequences: loss of accuracy, generation of spurious noise, local optima, non-differentiability, etc.

To definitely overcome these difficulties, T. Hughes proposed a few years ago to consider a design process entirely based on NURBS, in which the simulation is achieved using parametrized surfaces and volumes instead of grids. In isogeometric analysis, a variational approach is carried out using a NURBS basis to define the geometry and solution fields, yielding high-order adaptive and hierarchical numerical schemes. An important feature is that computations are performed using the "exact" geometry, i.e., without approximating the geometry defined by the CAD tool.

In this presentation, we examine theoretical and practical features of this emerging design optimization approach and underline the differences with respect to the classical methods. Advantages as well as new issues will be presented. We illustrate the talk with several examples from various fields, such as heat conduction, linear elasticity, or non-linear fluid dynamics.

Date: *08.04.2010*
Time: *09:00 – 09:45*

A Superficial Survey of Routes to Interactive Analysis.

Malcolm Sabin

The immediate roadblock in the road to better integration of design with analysis is the meshing activity, which requires significant processing with manual input. However, concern about this may take our minds off the road beyond, where the real objective is bringing analysis into the design loop. Beyond that again is integration of analysis into design optimization.

This talk covers the issues we need to be thinking about for the next stage. It takes a very broad brush view, looking at different things which need to be analysed, different kinds of analysis, different kinds of shapes, and different kinds of things that can go wrong.

Date: *08.04.2010*
Time: *10:00 – 10:45*

Some Results about IsoGeometric Analysis.

Giancarlo Sangalli

IsoGeometric Analysis (IGA) is a novel technique for the discretization of partial differential equations. It was introduced by T. Hughes and co-authors in 2005 and since then it has been having a growing impact on several scientific communities, from mechanical engineering to geometry modelling and numerical analysis.

IGA methodologies are designed with the aim of improving the connection between numerical simulation of physical phenomena and the Computer Aided Design systems. Indeed, the ultimate goal is to eliminate or drastically reduce the approximation of the computational domain and the re-meshing by the use of the "exact" geometry directly on the coarsest level of discretization. This is achieved by using B-Splines or Non Uniform Rational B-Splines for the geometry description as well as for the representation of the unknown fields. The use of Spline or NURBS functions, together with isoparametric concepts, results in an extremely successful idea and paves the way to many new numerical schemes enjoying features that would be extremely hard to achieve within a standard finite element framework. Splines and NURBS, and their non-tensor product generalizations as T-splines, offer a flexible set of basis functions for which refinement, de-refinement, and degree elevation are extremely inexpensive and whose inter-element regularity can be tuned according to, e.g., a–priori knowledge of the unknown solution or a–posteriori techniques.

In this talk, after a short introduction about IsoGeometric analysis, I will discuss our recent results on the use of NURBS and Splines based discretizations for vector fields computations as well as our experience on the use of T-splines as a tool for local refinement.

Date: *08.04.2010*
Time: *11:15 – 12:00*

Image Denoising and Simplification with Higher Order PDEs.

Stephan Didas

Nonlinear diffusion filtering and regularization methods are established tools for adaptive image simplification. Nevertheless, they show some limitations in practice if the image data is not piecewise constant. This drawback can be circumvented by using higher derivative orders in regularisation or PDE-based methods. With these methods, one can obtain piecewise higher degree polynomial approximations of the given data. This approach can not only be used for grey-value images, but also for tensor-valued data. In this setting, there are some interesting open questions, for example concerning a suitable stability notion of methods for tensor data.

Date: *09.04.2010*
Time: *09:00 – 09:45*

Discretization of Convex Variational Regularization.

Christiane Pöschl

Consider a nonlinear ill-posed operator equation $F(u) = v$ with F acting between two Banach spaces U and V. For solving it numerically, one has to deal with finite approximations of the spaces, with noisy data v^δ, and with approximations of the operator F. We analyze convex regularization for such an equation, which takes into account all these realistic aspects. More precisely, we show *(semi-)convergence* of the regularization method. Applications to total variation and bounded deformation are discussed.

Date: *09.04.2010*
Time: *10:00 – 10:45*

Cubic G^1 Interpolatory Splines with Small Strain Energy.

Gašper Jaklič

A construction of a planar cubic G^1 interpolatory spline through given sequence of data points will be presented. Since tangents at interpolation points are supposed to be unknown, they are automatically determined in such a way that an appropriate approximation of the strain energy is minimized. The method is entirely local, and the resulting curve is regular, locally without loops, cusps, and folds.

A similar approach can be applied for a construction of planar parametric Hermite cubic interpolants with small curvature deviation. By a minimization of an appropriate approximate functional, it is shown that a unique solution exists, and it has a nice geometrical interpretation. Asymptotically the best solution of such a problem is a quadratic geometric interpolant. The approach can be combined with strain energy minimization.

Date: *09.04.2010*
Time: *11:15 – 11:35*

Envelope Computation by Approximate Implicitization.

Tino Schulz

We consider a moving parametric curve in a certain region of interest. We discuss how approximate implicitization (AI) can be used for finding a piecewise algebraic curve representing the envelope. The envelope is defined as the zero set of a function in the parameter space combining the curve parameter and the motion parameter. We analyze the connection of this function to the implicit equation of the envelope. This enables us to use AI for the computation of the (exact or approximate) algebraic representation of the envelope. Based on these results we derive an algorithm for computing a piecewise approximation of chosen degree and demonstrate its performance by several examples.

Date: *09.04.2010*
Time: *11:35 – 11:55*

Recent Developments in Shearlet Theory.

Philipp Grohs

In my talk I will consider the problem of representing a function in a non-adaptive fashion such that oscillatory behavior (singularities, shocks, edges,...) can be handled effectively. In one dimension the wavelet transform does a good job at this task. But as the dimension becomes larger, the wavelet transform does not possess sufficient frequency resolution to describe the subtle geometric phenomena that occur at microscopic scales.

At least on the theoretical side, for bivariate functions, a satisfactory solution to this problem has been given by the introduction of the curvelet transform by Candès/Donoho and later the shearlet transform by Labate et al. (the latter possessing certain computational advantages). However, all of the known curvelet and shearlet constructions up to date are rather specific and not localized in space.

I will discuss some more general constructions of shearlets which can be localized in space while still retaining the desirable theoretical properties of previous constructions.

Date: *09.04.2010*
Time: *11:55 – 12:15*