Martin Rumpf

Academic career

1992	Dr. rer. nat., University of Bonn
1993 - 1996	Postdoc, University of Freiburg
1996 - 2001	Professor (C3), University of Bonn
2001 - 2004	Professor (C4), University of Duisburg-Essen
Since 2004	Professor (C4/W3), University of Bonn

Offers

2002	Chair in Mathematics, University of Zürich, Switzerland
2003	Chair, MATHEON, FU Berlin
2012	Director position of the Weierstrass Institute Berlin combined with a chair at the HU Berlin

Invited Lectures

2003	Plenary lecture, GAMM annual meeting, Padua / Abano Terme, Italy
2004	Plenary lecture, SIAM Conference on Image Science, Salt Lake City, UT, USA
2005	Plenary lecture, EQUADIFF, Bratislava, Slovakia
2006	Plenary lecture, Curves and Surface, Avignon, France
2008	Lecture course, CIME summer school, Cetraro, Italy
2010	Lecture course, CNA summer school, Pittsburgh, PA, USA
2013	Plenary lecture, SSVM, Graz, Austria
2015	Lecture course, CRC summer school, Barcelona, Spain
2016	Geometry Summit, Berlin

Research Projects and Activities

DFG Cluster of Excellence "Hausdorff Center for Mathematics"
Deputy coordinator, 2006 – 2012
DFG Cluster of Excellence "Hausdorff Center for Mathematics"
Member of the Board of Directors, since 2006
DFG project "Discrete Riemannian calculus on shape space"
jointly with Karl-Theodor Sturm, in the Collaborative Research Center SFB 1060 "The Mathematics of Emergent Effects", 2012 - 2020
DFG project "Numerical optimization of shape microstructures"
jointly with Sergio Conti, in the Collaborative Research Center SFB 1060 "The Mathematics of Emergent Effects", 2012 - 2020
DFG project "Geodesic Paths in Shape Space"
in the research network of the FWF S117 "Geometry + Simulation", 2012 - 2020
DFG Collaborative Research Center SFB 1060 "The Mathematics of Emergent Effects"
Deputy coordinator, since 2014
Conference "Panorama of Mathematics" (Bonn),
Organizer, 2015
GIF project "A Functional Map Approach to Shape Spaces"
by the German-Israeli Foundation for Scientific Research and Development, jointly with Miri Ben-Chen, 2017 - 2020
Series of Oberwolfach Workshops on "Image and Surface Processing"
Organizer, 2005, 2007, 2011, 2016

Research profile

Variational problems and evolution problems arising in computer vision, in geometry processing, and in materials science are the major driving force of my research.

In computer vision I'm interested in the infinite dimensional geometry of shape spaces equipped with a Riemannian metric which is motivated by physical models of viscous dissipation. A central theme is a general variational time discrete Riemannian calculus on different shape spaces, including discrete geodesics, exponential map and parallel transport. Applications are warping of images or shell surfaces, shape extrapolation, and pattern or texture transfer. A comprehensive convergence theory based on Γ convergence, finite element and ODE estimates on Hilbert spaces could be developed. I'm also interested in the close links to the theory of optimal transport.
A major goal is to treat textured images and explore inherent multiple scales in image maps. To this end images are considered as pointwise maps into some patch manifold, describing local, high dimensional texture and structure. Furthermore, spline curves and other low dimensional, smooth submanifolds will be particular interest in time dependent data analysis and in geometry animation.
With respect to materials science, I'm particularly interested in two-scale elastic shape optimization and the formation of optimal branching and folding patterns in elastic materials. The minimization of compliance type cost functionals leads to microstructured shapes and branching patterns arising naturally at material interfaces or at boundary incompatibilities.
My focus is on robust a posteriori error control using functional error estimates for BV functionals, duality techniques and relaxation. The aim is an efficient simulation and optimization of the microscopic patterns, and a better understanding of branching-type patterns observed in natural elastic structures, as for example bones and thin sheets. The vision is to carry over the two-scale analysis of elastic bulk material to thin elastic plates and shells.

Editorships

- Computing and Visualization in Science (since 1999)
- SIAM Journal on Imaging Science (since 2007)
- SIAM Journal on Numerical Analysis (since 2015)
- Journal of Mathematical Imaging and Vision (since 2015)

Research Area A I'm studying a general, time discrete Riemannian calculus on different shape

spaces, e.g. spaces of 2D surfaces, which physically behave like viscous shells, or spaces of images, where the metric encodes the cost of viscous transport and intensity changes along transport paths. The discretization is based on a proper approximation of the squared Riemannian distance by a functional on consecutive objects along a discrete path in shape space. The available tools of the derived discrete geodesic calculus are a discrete path energy, discrete geodesics, discrete logarithm, discrete exponential map, discrete parallel transport, discrete covariant derivative, and finally a discrete curvature tensor on shape space.
Application examples are image warping, extrapolation of image sequences, and pattern or texture transfer. In the context of Hilbert manifolds, we could establish a comprehensive convergence theory based on Γ convergence, finite element and ODE estimates on Hilbert spaces could be developed [6, 3]. We also study generalized spaces of images, where an image is no longer based on a pointwise image intensity value but a high dimensional texture and structure description. I'm investigating time discrete Riemannian splines in shape spaces with applications to smooth image key frame interpolation, compression and video processing [9].Furthermore, we integrated concepts from optimal transport and we studied a pure optimal transport model with source term [5]. Finally, I´m interested in the numerical approximation of optimal transport on discrete metric measure spaces.

Research Area B I´m investigating elastic shape optimization with a particular emphasis on

two-scale models and on risk averse stochastic optimization [8]. Here, the minimization of compliance type cost functionals leads to microstructured shapes and via an additional interfacial cost a particular scale can be selected. In fact, in the limit of vanishing interfacial cost branching patterns represent optimal elastic shapes.
Furthermore, branching patterns arise naturally at material interfaces, at boundary incompatibilities, and in compressed thin films, and are determined by the competition of elastic and

interfacial energies. Moreover, I'm studying the formation of optimal branching and folding patterns in elastic materials. For simple model problems we studied rigorous a posteriori error estimates and for the two scale models error estimates based on the dual weighted residual approach [2]. Furthermore, we could improve the upper energy bound for branching patterns at austenite-martensite interfaces [1]. We use phase field models [10] for the numerical approximation of optimal branching structures with the aim to better understand branching-type patterns observed in natural elastic structures, as for example bones and graphene sheets.

Selected PhD students

Olga Wilderotter (2001): "Adaptive Finite-Elemente-Methode für singuläre parabolische Probleme",
now Professor, HS Karlsruhe
Ulrich Weikard (2002): "Numerische Loesungen der Cahn-Hilliard-Gleichung und der Cahn-Larche-Gleichung",
now Senior Economist, DekaBank Deutsche Girozentrale
Tobias Preußer (2003): "Anisotropic Geometric Diffusion in Image and Image-Sequence Processing",
now Professor, Jacobs University Bremen, and Member of Management Board, and Head of Modelling & Simulation, Fraunhofer MEVIS, Bremen
Robert Strzodka (2004): "Hardware Efficient PDE Solvers in Quantized Image Processing",
now Professor, University of Heidelberg
Benedikt Wirth (2010): "Variational Methods in Shape Space",
now Associate Professor, University of Münster
Benjamin Berkels (2012): "Joint Methods in imaging based on diffuse image representations",
now Professor, RWTH Aachen

Selected publications

[1] Patrick Dondl, Behrend Heeren, and Martin Rumpf. Optimization of the branching pattern in coherent phase transitions. *C. R. Math. Acad. Sci. Paris*, 354(6):639–644, 2016.

[2] Benedict Geihe and Martin Rumpf. A posteriori error estimates for sequential laminates in shape optimization. *Discrete Contin. Dyn. Syst. Ser. S*, 9(5):1377–1392, 2016.

[3] B. Berkels, A. Effland, and M. Rumpf. Time discrete geodesic paths in the space of images. *SIAM J. Imaging Sci.*, 8(3):1457–1488, 2015.

[4] Benjamin Berkels, Alexander Effland, and Martin Rumpf. A posteriori error control for the binary mumford-shah model. *Mathematics of Computation*, 2015.

[5] Jan Maas, Martin Rumpf, Carola Schönlieb, and Stefan Simon. A generalized model for optimal transport of images including dissipation and density modulation. *ESAIM Math. Model. Numer. Anal.*, 49(6):1745–1769, 2015.

[6] Martin Rumpf and Benedikt Wirth. Variational time discretization of geodesic calculus. *IMA J. Numer. Anal.*, 35(3):1011–1046, 2015.

[7] Oliver Arold, Sebastian Bauer, Benjamin Berkels, Svenja Ettl, Joachim Hornegger, and Martin Rumpf. Joint surface reconstruction and 4d deformation estimation from sparse data and prior knowledge for marker-less respiratory motion tracking. *Medical Physics*, 40(9):091703, 2013.

[8] Benedict Geihe, Martin Lenz, Martin Rumpf, and Rüdiger Schultz. Risk averse elastic shape optimization with parametrized fine scale geometry. *Math. Program.*, 141(1-2, Ser. A):383–403, 2013.

[9] Behrend Heeren, Martin Rumpf, Max Wardetzky, and Benedikt Wirth. Time-discrete geodesics in the space of shells. *Comput. Graph. Forum*, 31(5):1755–1764, 2012.

[10] Patrick Penzler, Martin Rumpf, and Benedikt Wirth. A phase-field model for compliance shape optimization in nonlinear elasticity. *ESAIM Control Optim. Calc. Var.*, 18(1):229–258, 2012.

[11] Sergio Conti, Harald Held, Martin Pach, Martin Rumpf, and Rüdiger Schultz. Risk averse shape optimization. *SIAM J. Control Optim.*, 49(3):927–947, 2011.

[12] U. Clarenz, U. Diewald, G. Dziuk, M. Rumpf, and R. Rusu. A finite element method for surface restoration with smooth boundary conditions. *Comput. Aided Geom. Design*, 21(5):427–445, 2004.

[13] Günther Grün and Martin Rumpf. Nonnegativity preserving convergent schemes for the thin film equation. *Numer. Math.*, 87(1):113–152, 2000.

[14] M. Flucher and M. Rumpf. Bernoulli's free-boundary problem, qualitative theory and numerical approximation. *J. Reine Angew. Math.*, 486:165–204, 1997.