AlfioBorzì

Professor of Mathematics

Teaching portfolio

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Languages

Italian ★★★★★
English ★★★★★
German ★★★★☆
French ★★☆☆☆

My research and teaching activities focus on modelling and scientific computing, analysis, theory and numerical analysis of differential equations, optimization with differential models, control of deterministic, quantum, and stochastic dynamical systems, inverse problems and imaging modalities. It is my wish to always being active in teaching and contribute to undergraduate and graduate programs, and to promote students in their studies based on a clear gender and multicultural equity attitude.

In my view, research and university teaching are inseparable also for the purpose of preparing new scientists and entrepreneurs. For this reason, I try to convey the latest concepts of applied and computational mathematics within 'standard' lectures. In addition, I regularly offer special lectures to make the latest research topics accessible to students. To support teaching and research at the master and PhD level, I have also written (and writing) the following books in which I present the latest achievements in some specialized research areas:

- A. Borzì, **The Sequential Quadratic Hamiltonian Method**, CRC/Chapman and Hall, 2022 (in preparation).
- A. Borzì, **Modelling with Ordinary Differential Equations: A Comprehensive Approach**, CRC/Chapman and Hall, Boca Raton and London, 2020 (ISBN 9780815392613).
- A. Borzì, G. Ciaramella and M. Sprengel, **Formulation and Numerical Solution of Quantum Control Problems**, SIAM, Philadelphia, 2017 (ISBN 978-1-611974-83-6).
- A. Borzì and V. Schulz, **Computational Optimization of Systems Governed by Partial Differential Equations**, SIAM, Philadelphia, 2012 (ISBN 978-1-611972-04-7).
- A. Borzì and M. Wogrin, **Equazioni Differenziali Ordinarie**, Hevelius Edizioni, Benevento, 2009 (ISBN 978-88-86977-63-0).

In particular, the book 'Modelling with ordinary differential equations: a comprehensive approach' is unique in that it presents a large variety of topics related to modelling with ODEs together and in a unified manner : theory of ODEs, systems of ODEs and ODEs of n-order, stability, boundary problems, numerical solution methods, calculus of variation, optimal control, inverse problems, differential games, stochastic differential equations, neural networks and ODEs.

I think that the study of mathematics should be promoted at very early age. For this reason, I have also published a book for children on the early history of mathematics :

A. Borzì, **In den Brunnen gefallen beim Sterne schauen - Eine sehr kurze Geschichte der Mathematik -**, epubli, Berlin, 2017 (ISBN 978-3-7450-3862-0)

I have been responsible to design and deliver series of lectures on multilevel methods, optimization and control, and numerical analysis of PDEs for PhD schools in the Philippines (Diliman), The Netherlands (Woudschoten-Zeist), Italy (Catania), Austria (Graz), Spain (Zaragoza), and Germany (Schloss Thurnau and Trier).

In addition, I have also offered advanced lectures on topics like multilevel optimization and control of stochastic models. Recently, I started lecturing on neural networks.

Before the present time of online lecturing, it was my preference to hold lectures in a classical fashion using the blackboard (also supported by other media) and to keep track of

the understanding of the lecture by motivating Students' questions and remarks. In topics like modelling and scientific computing, I organize part of my lectures in appropriate computer rooms. I also encourage very much the students to make projects (alone or in a group) based on the content and purpose of the lectures. At the moment, I am working on adapting my teaching modalities to the online regime.

It has been my pleasure to deliver lectures in Italian, English, and German for scientists and for the general public including lectures for children.

Main teaching topics

1) Analysis (Real, Functional, Nonlinear, Complex) 2) ODE and PDE theory; 3) Optimization and optimal control theory; 4) Numerical analysis of ODE and PDE problems; 5) Numerical linear algebra and multilevel methods; 6) Simulation and control of quantum and stochastic systems; 7) Imaging analysis and inverse problems; 8) Modelling and scientific computing.

In particular, I have taught the following courses:

Analysis I and II, Linear Algebra I and II, Optimization I and II, Operations Research, Complex Analysis, Functional Analysis, Applied Analysis, Nonlinear Analysis, Ordinary Differential Equations, Programming in C++, Numerical Analysis I and II, Theory of Partial Differential Equations, Optimal Control Theory, Multigrid Metheods, Multilevel Methods in Optimization with PDE models, Numerical Solution of Partial Differential Equations, Modeling and Scientific Computing, Simulation and Optimal Control of Quantum and Stochastic Systems, Implementation of Deep Learning Algorithms, Numerical Analysis of Optimal Control Problems with Differential Models.

A complete list of my teaching activity of the last 15 years is given at the end of this document.

Components of my teaching portfolio

My personal teaching philosophy is to pass through my knowledge and enthusiasm in mathematics and in the sciences in a way that makes the acquired knowledge rigorous and multifaceted. With this aim in mind, I always try to link the content of my lectures with up-to-date topics in biology, economics and finance, natural and social sciences, and engineering.

Enthusiasm can be conveyed, apart of my personal attitude, by providing the historical and personal context in which the particular topic was developed (or is developing), and by outlining the connections to other topics and to other sciences and technology, and the society. For this purpose, I also suggest the reading of books about the history of science, biographies, etc..

Rigorous mathematical knowledge means to discuss proofs of theorems and the meaning and importance of the postulates that are at the basis of the mathematical discussion. For this reason, I also take care of choosing books that provide a rigorous and possibly general discussion and complement the given reading list with exercises and alternative proofs if necessary.

I am convinced that any mathematical topic can be better conveyed by visualisation, and I put a particular effort during my lectures to provide visual materials and examples that are many times drawn from, e.g., physics, biology, economics and social sciences. In addition, in computer simulation and numerical optimization, I stress the importance of developing approximations and solution algorithms with proved convergence and possibly optimal computational complexity, and to verify these properties by validation.

OS & Coding

GNU/Linux ★★★★★
MacOS ★★★★★
Fortran ★★★★★
MATLAB ★★★★★
Python ★★★★★
C++ ★★★★★

Furthermore, I emphasize the importance of communicating science and teach to my students how to present a mathematical work (for example, the result of a project) to an audience and in a paper.

The evaluation that I get from the students is variable and depends on the topic and the level of the course. Specifically, in the basic but fundamental course of Analysis, students recognise my effort in clarifying concepts and methods and appreciate my enthusiasm and openness to discussion; on the other hand, some students complain about the amount of material that should be covered. However, in master courses (e.g., Numerical Analysis of PDEs) the situation concerning the latter point is different: the students appreciate to include emerging methodologies in view of their master thesis and beyond.

A recent case is the emerging importance of deep learning in society. Thus, I started including elements of machine learning in my teaching and organised a course concerning the detailed implementation of deep learning algorithms, which are essentially based on approximation and optimisation tools. Since then, I have supervised three master thesis, and in my ODE book a chapter is devoted to neural networks and differential problems. The BMBF project iDeLIVER is now supporting a PhD student (Nadja Vater) working on neural networks for medical imaging.

Supervision of PhD Thesis

- **T. Breitenbach**, *A sequential quadratic Hamiltonian scheme for solving optimal control problems with non-smooth cost functionals*, PhD Math. Thesis, Univ. Würzburg, 2019.
- **D. Kioi Gathungu**, *On multigrid and H-matrix methods for partial integro-differential equations*. PhD Math. Thesis, Univ. Würzburg, 2017.
- **M. Sprengel**, *A theoretical and numerical analysis of a Kohn-Sham equation and related control problems*, PhD Math. Thesis, Univ. Würzburg, 2017.
- **B. Gaviraghi**, *Theoretical and numerical analysis of Fokker-Planck optimal control problems for jump-diffusion processes*. PhD Math. Thesis, Univ. Würzburg, 2017.
- **A. Schindele**, *Proximal methods in medical image reconstruction and in nonsmooth optimal control of partial differential equations*. PhD Math. Thesis, Univ. Würzburg, 2016.
- **J. Merger**, *Optimal control and function identification in biological processes*. PhD Math. Thesis, Univ. Würzburg, 2016.
- **S. Wongkaew**, *On the control through leadership of multi-agent systems*. PhD Math. Thesis, Univ. Würzburg, 2015.
- **G. Ciaramella**, *Optimal control of quantum spin systems*. PhD Math. Thesis, Univ. Würzburg, 2015.
- **M. Mohammadi**, *Discretization of the Fokker-Planck equation and related control systems*. PhD Math. Thesis, Univ. Würzburg, 2015.
- **M. Munir Butt**, *Formulation and multigrid solution of Cauchy-Riemann optimal control problems*, PhD Math. Thesis, Univ. Graz, 2011.
- **M. Vallejos**, *Multigrid optimization methods for elliptic optimal control problems*. PhD Math. Thesis, Univ. Graz, 2008.

Ongoing:

- **Jan Bartsch**, *Optimal control of Boltzmann models with Monte-Carlo methods*, PhD Math. Thesis, ongoing.

- **Francesca Calà Campana**, *Differential Nash games*, PhD Math. Thesis, ongoing.
- **Nadja Vater**, *Multilevel-multiscale convolutional neural networks*, PhD Math. Thesis, ongoing.
- **Jacob Körner**, *Modelling and control of stochastic models from behavioural epidemiology*, PhD Math. Thesis, ongoing.

Supervision of Master Thesis

- **Sebastian Hofmann**, *Sequential quadratic Hamiltonian schemes for training Runge-Kutta structured neural networks*, MSc Math. Thesis, Univ. Würzburg, 2021.
- **Max Steinlein**, *The Pontryagin maximum principle for solving Liouville optimal control problems*, MSc Math. Thesis, Univ. Würzburg, 2020.
- **Jonas Kleieisel**, *Continuous models of pulse-coupled neural networks for image segmentation*, MSc Math. Thesis, Univ. Würzburg, 2020.
- **Nico Nees**, *A FEM-SQH Framework for Solving Elliptic Optimization Problems*, MSc Math. Thesis, Univ. Würzburg, 2020.
- **Andreas Seufert**, *On the SSN and SQH methods for solving non-smooth optimal control problems*, MSc Math. Thesis, Univ. Würzburg, 2020.
- **Nadja Henning (now Vater)**, *Nested iteration for approximation with neural networks*, MSc Math. Thesis, Univ. Würzburg, 2019.
- **Jan Bartsch** , *Optimal control problems governed by Liouville models - Mathematical analysis and implementation*, MSc Math. Thesis, Univ. Würzburg, 2018.
- **Melina-Loren Kienle Garrido**, *On the optimal control of a new cancer therapy model*, MSc Math. Thesis, Univ. Würzburg, 2017. (with publication in Journal)
- **Lisa Schäfer**, *A mathematical investigation of a new Lorentz-covariant heat conduction model*, MSc Math. Thesis, Univ. Würzburg, 2017.
- **Marc Herrmann**, *Analysis of discretization of a modified Crank-Nicolson scheme for quantum optimal control problems*, MSc Math. Thesis, Univ. Würzburg, 2016.
- **Andrea Thomann**, *Stability and accuracy of a pseudospectral scheme for the Wigner function equation*, MSc Math. Thesis, Univ. Würzburg, 2015. (with publication in Journal)
- **Veronika Thalhofer**, *Formulation and investigation of a new stochastic hybrid system for subtilin production and the corresponding Fokker-Planck equation*, MSc Math. Thesis, Univ. Würzburg, 2015. (with publication in Journal)
- **Thomas Fischer**, *A numerical approach for solving a Fokker-Planck controllability problem*, MSc Math. Thesis, Univ. Würzburg, 2015.
- **Frank Beislein**, *Efficient algorithms for detection of particles and filaments*, MSc Math. Thesis, Univ. Würzburg, 2014.
- **Alexander Klüber**, *The numerical solution of elliptic integro-differential equations with applications*, MSc Math. Thesis, Univ. Würzburg, 2014.
- **Julia Kwasny**, *Investigation of a robust single particle tracking algorithm*. MSc Math. Thesis, Univ. Würzburg, 2013.
- **Michael Götz**, *Optimal Control of Spin Systems using Newton's Method and Symplectic Discretization*, MSc Math. Thesis, Univ. Würzburg, 2013.

- **Juri Merger**, *A Lie algebraic and numeric investigation of the Black-Scholes equation with Heston volatility model*, MSc Math. Thesis, Univ. Würzburg, 2013.
- **Lisa Radnai**, *Two Efficient Methods for Optimal Control of a Mass Transport Problem*, MSc Math. Thesis, Univ. Würzburg, 2012.
- **Roberta Mancini**, *An adjoint-based optimization scheme for solving time-domain electromagnetic inverse scattering problems*, MSc Eng. Thesis, Univ. Sannio, 2009.
- **Dora Russo**, *A Bayesian Sequential Probing Method to Electromagnetic Inverse Problems*, MSc Eng Thesis, Univ. Sannio, 2009.
- **Elisabeth Decker**, *Spectral methods for the Schrödinger equation*. MSc Math. Thesis, Univ. Graz, 2005. (with publication in Journal)

Ongoing:

- **Melissa Finster**, *Analysis of spatially distributed synchronised FitzHugh-Nagumo oscillators*, MSc Math. Thesis, ongoing.
- **Hannah Weinmann**, *Synchronisation of a network of consumer-resource models and Heider social balance theory*, MSc Math. Thesis, ongoing.
- **Anna Rauch**, *Hierarchical normalized cuts segmentation and classification by neural networks*, MSc Math. Thesis, ongoing.
- **Sarah Winkelmann**, *Optimal design with Liouville equation for optical systems*, MSc Math. Thesis, ongoing.

Supervision of Bachelor Thesis

- **K. Schneider**, *Über einen Algorithmus für Stereovision* (01/2017)
- **J. Bartsch**, *Optimal Control of Androgen Suppression for Prostate Cancer* (09/2016)
- **M. Krauß** , *Ein mathmatisches Modell zur radiologischen Behandlung von Tumorzellen unter Berücksichtigung stochastischer Störeinflüsse* (04/2014)
- **C. Y. Schwemin**, *Ein mathmatisches Modell des Tumorzellwachstums* (01/2014)
- **A. Thomann**, *Die Numerische Simulation von Pilzmyzel Wachstsum mit Reaktions-Diffusions Gleichungen* (09/2013)
- **S. Juschkat** , *Stochastische Modellierung von Weingärung* (02/2013)
- **V. Thalhofer** , *Optimale Steuerung von Bloch Systemen mit symplektischer Diskretisierung* (09/2012)
- **F. Gabel** , *Berechnung des optischen Flusses mit der Horn-Shunck-Methode und der Methode von Kazufimo Ito* (08/2012)
- **C. Müller** , *Die Fokker-Planck Steuerungsmethode für eindimensionale stochastische Prozesse* (12/2011)

Youtube Videos

In my opinion, the act of teaching means also stimulating curiosity and enthusiasm for a scientific topic in all people. For this reason, I try to go beyond the lecture room and whenever possible I post a youtube video about mathematics and sciences.

- **Alfio's Math** : `https://www.youtube.com/watch?v=ju6rG_7Z_5I`
- **Quantenmechanik - Von Democritus bis Schrödinger** : `https://www.youtube.com/watch?v=BTiPcnT_QKc`

- **Quantenkontrolle - Die Zukunft der Wissenschaft!** : https://www.youtube.com/watch?v=OOKMy9OzXuM
- **Malthus & Verhulst, die Bevölkerungsentwicklung und die Weingärung** : https://www.youtube.com/watch?v=NtLnp1cUPmc
- **Einstein & Co. und die Revolution des Aktienhandels** : https://www.youtube.com/watch?v=Qb4obyF7c9I
- **On the optimal control of a Kohn-Sham quantum model - Workshop PRACQSYS 2018 at IHP Paris** : https://www.youtube.com/watch?v=6chQrO2uInY&index=53&list=PL9kd4mpdvWcAMYt4Fhw0dgBPF24bQmDGz

Calender of teaching activity

(Semestre estivo=Sommersemester=Summer term)

(Semestre invernale=Wintersemester=Winter term)

- **University of Würzburg**:
  Sommersemester 2020:
- SOSE 2020. Partielle Differentialgleichungen der Mathematischen Physik, 4 St., online
- SOSE 2020. Mathematik für Informatikerinnen, 5 St. (half course, analysis), online
- WISE 2019-20. Modellierung und Wissenschaftliches Rechnen, 4 St.
- WISE 2019-20. Numerik partieller Differentialgleichungen, 4 St..
- SOSE 2019. Optimale Steuerung (Calculus of Variation ODE, Optimal Control ODE, Optimal Control PDE), 3 St.
- SOSE 2019. Übungen zu Optimale Steuerung (Exercises) 1 St.
- SOSE 2019. Seminar Optimierung (Selected Topics on the Theory and Numerics of the Calculus of Variation ODE, Optimal Control ODE, Optimal Control PDE) 2 St.
- SOSE 2019. Seminar Wissenschaftliches Rechnen (Neural Networks, Deep Learning), 2 St.
- SOSE 2019. Arbeitsgemeinschaft Wissenschaftliches Rechnen (Simulation of Evolution Models: Lattice-Boltzmann, Boltzmann, Fokker-Planck, Bio-Chemical Reaction Diffusion, Turing Morphogenesis), 4 St.
- WISE 2018-19. Modellierung und Wissenschaftliches Rechnen, 4 St.
- WISE 2018-19. Nichtlineare Analysis, 3 St.
- SOSE 2018. Frei Semester.
- WISE 2017-18. Modellierung und Wissenschaftliches Rechnen, 4 St.
- WISE 2017-18. Numerik partieller Differentialgleichungen, 4 St..
- SOSE 2017. Analysis 2, 4 St.
- WISE 2016-17. Analysis 1, 4 St.
- WISE 2016-17. Modellierung und Wissenschaftliches Rechnen, 4 St.
- SOSE 2016. Gewöhnliche Differentialgleichungen (GMR)
- SOSE 2016. AG & Seminars
- WISE 2015-16. Numerik für die optimale Steuerung von Modellen mit Differentialgleichungen, 4 St.
- WISE 2015-16. Modellierung und Wissenschaftliches Rechnen, 4 St.
- SOSE 2014. Angewandte Analysis, 4 St..
- SOSE 2014. Seminar Simulation und Optimierung mit Differentialgleichungen, 2 St.
- WISE 2013-14. Modellierung und Wissenschaftliches Rechnen, 4 St..
- WISE 2013-14. Numerik partieller Differentialgleichungen, 4 St..
- SOSE 2013. Frei Semester.
- WISE 2012-13. Analysis II, 4 St..
- WISE 2012-13. Modellierung und Wissenschaftliches Rechnen, 4 St..
- WISE 2012-13. Seminar Simulation und Optimierung mit Differentialgleichungen, 2 St.
- WISE 2011-12. Modellierung und Wissenschaftliches Rechnen, 4 St..
- SOSE 2012. Analsys I, 4 St..
- SOSE 2012. Multigrid Methods and Optimization I, 4 St..
- WISE 2011-12. Numerik partieller Differentialgleichungen, 4 St..
- SOSE 2011. c(08 00290) Operations Research, 3 St.. (08 00300) Uebungen zu Operations Research, 1 St..
- SOSE 2011. (08 03590) Seminar Partielle Differentialgleichungen, 2 St..
- **University of Graz**:1998/99 Wintersemester
  621.923 W Analysis I 2 UE
- 1998/99 Sommersemester
  621.912 S Analysis II 2 UE
- 1999/2000 Wintersemester
  621.923 W Analysis I 2 UE

- 1999/2000 Sommersemester
  621.911 S Analysis II 2 UE
- 2000/2001 Wintersemester
  621.706 W Funktionentheorie (complex analysis) 2 PS
- 2000/2001 Sommersemester
  621.706 S Differentialgleichungen (theory of ODEs and applications) 2 PS
- 2001/2002 Winteresemester
  621.951 W Programmieren für LehramtskandidatInnen (C++ programming) 2 PS
  621.952 W Programmieren für LehramtskandidatInnen 2 PS
- 2002/2003 Wintersemester
  621.316 W Differentialgleichungen für LehramtskandidatInnen 2 VO
  621.971 W Differentialgleichungen für LehramtskandidatInnen 1 PS
  621.972 W Differentialgleichungen für LehramtskandidatInnen 1 PS
- 2002/2003 Sommersemester
  621.318 S Numerische Mathematik für LehramtskandidatInnen (numerical analysis I) 2 VO
  621.319 S Numerische Mathematik für LehramtskandidatInnen 2 PS
- 2003/2004 Wintersemester
  621.036 W Partielle Differentialgleichungen (theory of PDEs) 4 VO
  621.037 W Proseminar aus Partielle Differentialgleichungen 2 PS
- 2003/2004 Sommersemester
  621.049 S Proseminar aus Gewöhnliche Differentialgleichungen und Funktionentheorie 1 PS
  621.318 S Numerische Mathematik für LehramtskandidatInnen 2 VO
- 2004/2005 Wintersemester
  621.316 W Differentialgleichungen für LehramtskandidatInnen 2 VO
  621.317 W Proseminar aus Differentialgleichungen für LAK 1 PS
- 2004/2005 Sommersemester
  621.318 S Numerische Mathematik für LehramtskandidatInnen 2 VO
  621.319 S Numerische Mathematik für LehramtskandidatInnen 2 PS
- 2005/2006 Wintersemester
  621.025 W Proseminar aus Differentialgleichungen 2 PS
  621.921 W Proseminar aus Lineare Algebra I 2 PS
- 2005/2006 Sommersemester
  621.038 S Optimierung I (optimization I) 4 VO
  621.142 S Multilevel methods in optimization with PDE models 2 VO
  621.921 S Proseminar aus Lineare Algebra II 2 PS
- 2006/2007 Wintersemester
  621.050 W Optimierung II (optimization II) 4 VO
  621.141 W Anleitung zu wissenschaftlichem Arbeiten in der Numerischen Mathematik 2 DW
  621.953 W Lineare Algebra I 2 UE
- 2006/2007 Sommersemester
  621.017 S Proseminar aus Funktionalanalysis 2 PS
  621.141 S Anleitung zu wissenschaftlichem Arbeiten in der Numerischen Mathematik 2 DW
  621.218 S Seminar Numerische Mathematik und Modellierung 2 SE
  621.318 S Numerische Mathematik für LehramtskandidatInnen 2 VO
- 2007/2008 Wintersemester
  621.005 W Höhere Mathematik I 2 UE
  621.810 W Multigrid methods 2 VO
  621.811 W Anleitung zu wissenschaftlichem Arbeiten in der Numerischen Mathematik 2 DW
  621.831 W Wissenschaftliches Seminar aus Angewandter Mathematik (Spezialseminar für DissertantInnen) 2 SE
- **University of Benevento**:
- CIV MAT07 Meccanica razionale (rational mechanics) 6 ECTS
- LS TLC MAT07 Metodi Numerici (numerical methods for telecomm. eng.) 4 ECTS
- 2008/2009 Semestre invernale
  LS CIV MAT05 Metodi matematici per l'ingegneria (numerical methods for civil eng.) 6 ECTS
  LS TLC - LS AUT MAT02 Algebra Lineare ed Equazioni Differenziali (lin. algebra and diff. eqs.) 6 ECTS

- 2008/2009 Semestre estivo
  CIV MAT07 Meccanica razionale 6 ECTS
  LS TLC MAT07 Metodi Numerici 4 ECTS
- 2009/2010 Semestre invernale
  LS CIV MAT05 Metodi matematici per l'ingegneria 6 ECTS
  LS TLC - LS AUT MAT02 Algebra - Algebra Lineare ed Equazioni Differenziali 6 ECTS