



# Alfio Borzi

Professor of Mathematics

## Teaching portfolio

### Address

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### Languages

Italian ★★★★★  
English ★★★★★  
German ★★★★★

My research and teaching activity focuses on modelling and scientific computing, analysis, theory and numerical analysis of differential equations, optimization with differential equations, control of deterministic, quantum, and stochastic dynamical systems, inverse problems and the mathematics of vision. It is my wish to always being active in teaching and contribute to undergraduate and graduate programs.

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

- A. Borzi, G. Ciaramella and M. Sprengel, **Formulation and Numerical Solution of Quantum Control Problems**, SIAM, Philadelphia, 2017 (ISBN 978-1-611974-83-6).
- A. Borzi and V. Schulz, **Computational Optimization of Systems Governed by Partial Differential Equations**, SIAM, Philadelphia, 2012 (ISBN 978-1-611972-04-7).

Further, to support my lecture activity, I have published/will publish the following books:

- A. Borzi, **Modelling with Ordinary Differential Equations: A Comprehensive Approach**, CRC/Chapman and Hall, London, to be published in 2019.
- A. Borzi and M. Wogrin, **Equazioni Differenziali Ordinarie**, Hevelius Edizioni, Benevento, 2009 (ISBN 978-88-86977-63-0).

These books integrate many years of teaching and research and are first written in form of lecture notes for my students. In my personal and my Chair's homepages, lecture notes and further information for students are available (in English and German).

At the moment, I am completing the book 'Modelling with ordinary differential equations: a comprehensive approach'.

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 (in German):

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

In the past, I was responsible to design series of lectures on numerical optimization with PDEs. These lectures on multilevel optimization, optimization with variational inequalities, POD methods, discretization of optimality systems, were held in PhD schools in the Philippines (Diliman), The Netherlands (Woudschoten-Zeist), Italy (Catania), Austria (Graz), Spain (Zaragoza), and Germany (Schloss Thurnau).

It is 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. I also encourage very much the students to make projects (alone or in a group) based on the content and purpose of the lectures.

It is my pleasure to deliver lectures in Italian, English, and German.

## Main teaching topics

1) ODE and PDE theory. 2) Optimization and optimal control theory 3) Numerical approximation of ODE and PDE problems. 4) Numerical linear algebra and multigrid methods. 5) Simulation and control of quantum and stochastic systems. 6) Imaging analysis and inverse problems. 7) Linear and nonlinear analysis.

**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, 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, 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 multi-faceted.

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.. (e.g., R. Netz and W. Noel, *The Archimedes Codex*, Weidenfeld & Nicolson, 2007).

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. Some known books that I usually suggest are the following:

- H. Amann and J. Escher, *Analysis I-II-III*, Birkhäuser, 2002.
- E.A. Coddington and N. Levinson, *Theory of Ordinary Differential Equations*, McGraw-Hill, 1955.
- L.C. Evans, *Partial Differential Equations*, AMS, 2010.
- P.G. Ciarlet, *Linear and Nonlinear Functional Analysis with Applications*, SIAM, 2013.
- J.W. Demmel, *Applied Numerical Linear Algebra*, SIAM, 1997.
- J.-L. Lions, *Optimal Control of Systems Governed by Partial Differential Equations*, Springer, 1971.
- D. G. Luenberger, *Optimization by Vector Space Methods*, John Wiley & Sons, 1969.
- B. Jovanović and E. Süli, *Analysis of Finite Difference Schemes*, Springer, 2014.
- D.R. Cox and H.D. Miller, *The Theory of Stochastic Processes*, Chapman & Hall / CRC, 1965.

**OS & Coding**  
GNU/Linux ★★★★★  
MacOS ★★★★★  
Fortran ★★★★★  
MATLAB ★★★★★  
C++ ★★★★★

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 physics, biology, economy and social sciences. In addition, I encourage and support computer simulation and visualisation.

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 recognize 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.

## Supervision of PhD Thesis

It is my greatest pleasure to supervise talented students to the point that they are able to autonomously do research and teaching and pursue their scientific career.

I am proud of my past PhD students:

- **Duncan Kioi Gathungu**, *On multigrid and H-matrix methods for partial integro-differential equations*. PhD Math. Thesis, Univ. Würzburg, 2017.
- **Martin Sprengel**, *A theoretical and numerical analysis of a Kohn-Sham equation and related control problems*, PhD Math. Thesis, Univ. Würzburg, 2017.
- **Beatrice Gaviraghi**, *Theoretical and numerical analysis of Fokker-Planck optimal control problems for jump-diffusion processes*. PhD Math. Thesis, Univ. Würzburg, 2017.
- **Andreas Schindele**, *Proximal methods in medical image reconstruction and in non-smooth optimal control of partial differential equations*. PhD Math. Thesis, Univ. Würzburg, 2016.
- **Juri Merger**, *Optimal control and function identification in biological processes*. PhD Math. Thesis, Univ. Würzburg, 2016.
- **Suttida Wongkaew**, *On the control through leadership of multi-agent systems*. PhD Math. Thesis, Univ. Würzburg, 2015.
- **Gabriele Ciaramella**, *Optimal control of quantum spin systems*. PhD Math. Thesis, Univ. Würzburg, 2015.
- **Masoumeh Mohammadi**, *Discretization of the Fokker-Planck equation and related control systems*. PhD Math. Thesis, Univ. Würzburg, 2015.
- **Muhammad Munir Butt**, *Formulation and multigrid solution of Cauchy-Riemann optimal control problems*, PhD Math. Thesis, Univ. Graz, 2011.
- **Michelle Vallejos**, *Multigrid optimization methods for elliptic optimal control problems*. PhD Math. Thesis, Univ. Graz, 2008.

Ongoing:

- **Tim Breitenbach**, *Efficient solution of PDE optimal control problems with the Pontryagin's maximum principle*, PhD Math. Thesis, ongoing.
- **Francesca Calà Campana**, *FP differential games*, PhD Math. Thesis, ongoing.

- **Jan Bartsch**, *Boltzmann models*, PhD Math. Thesis, ongoing.

## Supervision of Master Thesis (selection out of 17)

The supervision of Master thesis has given me always great satisfaction: it is the unique opportunity for very young students to taste the pleasure of achieving new results. The following Students were able to do great original research work :

- **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.
- **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)
- **Julia Kwasny**, *Investigation of a robust single particle tracking algorithm*. MSc Math. Thesis, Univ. Würzburg, 2013.
- **Roberta Mancini**, *An adjoint-based optimization scheme for solving time-domain electromagnetic inverse scattering problems*, MSc Math. Thesis, Univ. Sannio, 2009.
- **Elisabeth Decker**, *Spectral methods for the Schrödinger equation*. MSc Math. Thesis, Univ. Graz, 2005. (with publication in Journal)

I have also supervised 10 Bachelor thesis. A complete list of thesis that I have supervised is available at my websites.

## 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](https://www.youtube.com/watch?v=ju6rG_7Z_5I)
- **Quantenmechanik - Von Democritus bis Schrödinger** : [https://www.youtube.com/watch?v=BTiPcnT\\_QKc](https://www.youtube.com/watch?v=BTiPcnT_QKc)
- **Quantenkontrolle - Die Zukunft der Wissenschaft!** : <https://www.youtube.com/watch?v=00KMy90zXuM>
- **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=6chQr02uInY&index=53&list=PL9kd4mpdvWcAMYt4Fhw0dgBPF24bQmDGz>

# Calendar of teaching activity

(Semestre estivo=Sommersemester=Summer term)

(Semestre invernale=Wintersemester=Winter term)

- **University of Würzburg:**
- 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 Wintersemester  
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