Friedrich-Alexander-Universität
Erlangen-Nürnberg

Friedrich-Alexander-Universität
DYNAMICS, CONTROL, MACHINE LEARNING AND NUMERICS

Students and young scientists
Internships

Chair for Dynamics, Control, Machine Learning and Numerics

Alexander von Humboldt Professorship

FAU DCN-AvH

Erlangen. March, 2023

FAU DCN-AvH Internships

Our internship program offers scholarships for young and highly motivated scientists interested on intensifying their training and research in Applied Mathematics and Data Sciences.

You will join a strong scientific community in an international atmosphere contributing to the scientific program of the FAU Chair for Dynamics, Control, Machine Learning and Numerics.

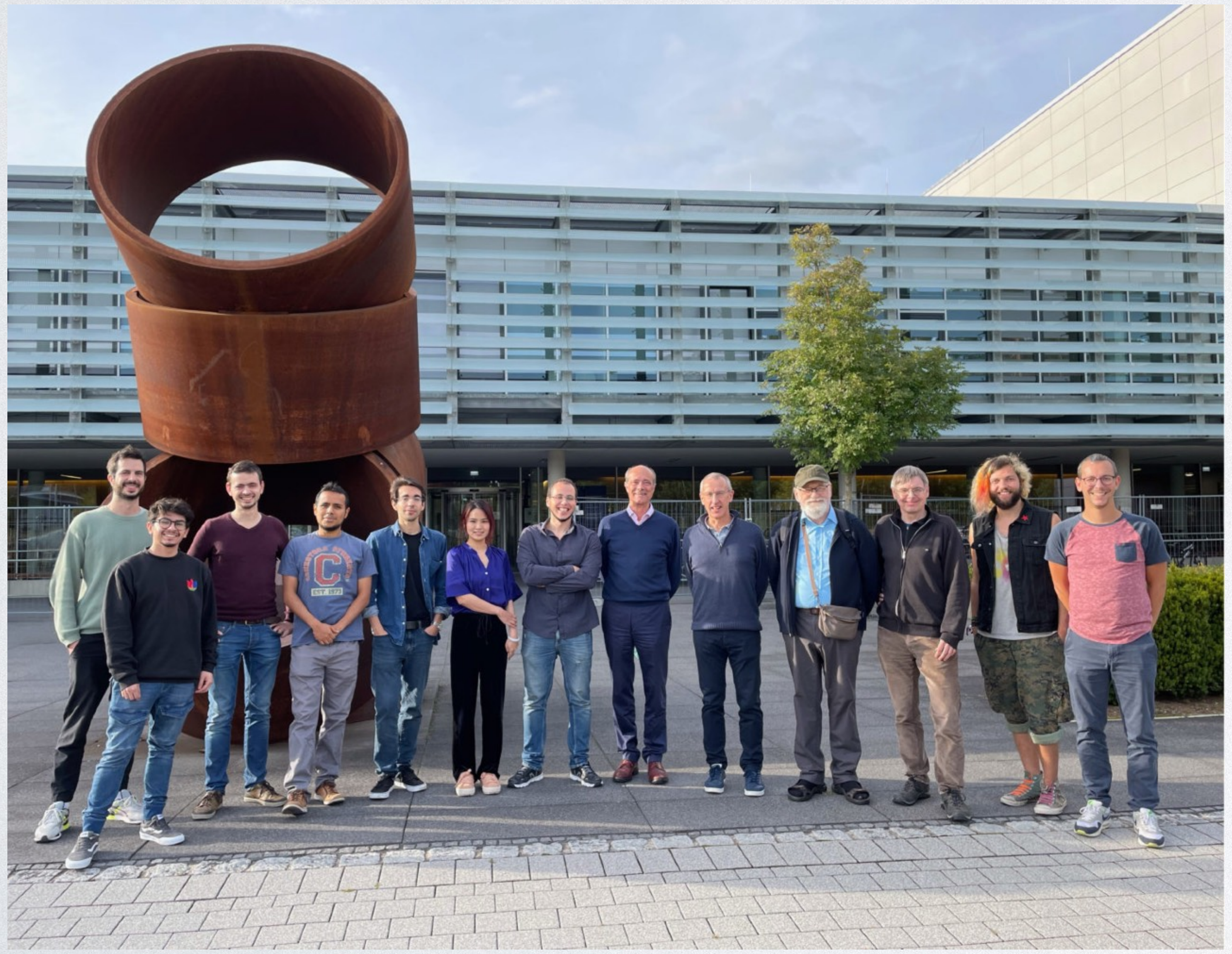
We aim the scholarship holder to become familiar with the most demanded, competitive and transversal skills through the involvement on a research project that can either be of theoretical, computational or applied nature.

We offer you our expertise and mentoring and a warm welcome.

FAU DCN-AvH Internships

Our Team

We actively work in the broad area of Applied Mathematics, developing and applying methods of Mathematical and Computational Mathematics to model, understand, design and control the dynamics of various phenomena arising in the interface of Mathematics with Engineering, Physics, Biology and Social Sciences. Nowadays we do it in conjunction with Machine Learning methods.



Where we are

Friedrich-Alexander-Universität
Erlangen-Nürnberg, Germany (FAU)
Department of Mathematics

www.dcn.nat.fau.eu

Felix Klein building
Cauerstraße 11, 91058 Erlangen,
Bavaria (Germany) View on Google maps!

FAU Friedrich-Alexander-Universität Erlangen-Nürnberg

FAU DCN-AvH Internships

We cover a broad array of topics in Mathematical and Data Sciences and applications including but not limited to:

- Analysis of Partial Differential Equations (PDE)
- Machine Learning
- Control of diffusion models arising in Biology and Social Sciences
- Modelling and control of multi-agent systems
- Hyperbolic models arising in traffic flow and energy transport
- Fractional PDE
- Optimal design in Material Sciences
- Micro-macro limit processes
- The interplay between discrete and continuous modelling in design and control
- The emergence of turnpike phenomena in long-time horizons
- Inversion and parameter identification

FAU DCN-AvH Internships

- Duration: between 1 - 6 months
- Highest international training and research standards
- Modern office space within a full-spectrum university
- Immersive networking experience into the FAU scientific community
- Shaping the pathways to a successful academic and research career

FAU DCN-AvH Internships

Steps to follow:

1- Check the open call: requirements, conditions, eligibility (dcn.nat.fau.eu/jobs)

2- Prepare your project proposal

3- Submit your application via webform at dcn.nat.fau.eu/jobs

Our internship management team will get in touch with you soon.

Please contact us for any further information at dcn@fau.de

FAU DCN-AvH Internships

A success example

Internship Program: Women in Mathematics of Data

Approximating the Wave Equation via Physics Informed Neural Networks: Various Forward and Inverse Problems

Internship report by **Dania Sana** (September 2022)

Supervised by Dr. **Yue Wang**

See full report: https://dcn.nat.fau.eu/approximating-the-1d-wave-equation-using-physics-informed-neural-networks-pinns/

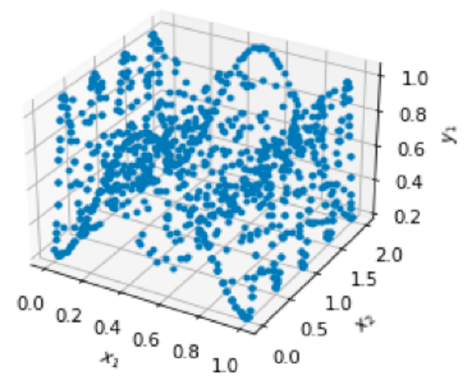


Figure 16: Best trained result

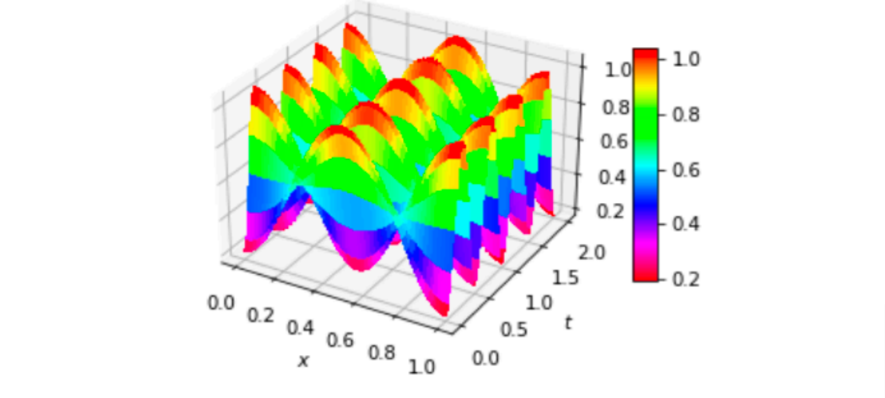


Figure 18: PINN-predicted solution to wave equation with Neumann boundary conditions

Abstract

This report summarizes the research activities and results obtained during the internship in the Research Center for Mathematics of Data in Erlangen. We present our progress on the application of Physics-Informed Neural Networks (PINNs) to solve various forward and inverse problems in PDEs, where we take the well-understood 1 dimensional wave equation as an example for numerical experiment and error analysis.

For forward problems (computing numerical solutions of given systems), we first establish a general framework of PINNs- that are trained using the loss functions to respect the governing physic laws and match the initial and boundary conditions. This model is able to solve the forward initial boundary valued problem (IBVP), and has shown promising numerical results in different cases even in the extreme case of no data. The requirement of accurate and fast prediction of numerical solutions is studied in two approaches: 1) Analyzing and evaluating the performance of the PINNs model by comparing its output to the analysis solution and examining the training and validation error; 2) in parallel, we review various structure and size of NN (number of nodes and layers) and investigate the required computational time, in order to achieve a satisfying performance of our model. More complicated cases, e.g. mixed boundary conditions, or degenerating wave equations, can be solved in the same framework.

For inverse problems, we generalize the PINNs algorithm to calculate the boundary control to realize the null controllability of the system in a given finite time. Additionally, we combine the model-driven and data-driven approach in solving the parameter identification problem.

This proposed PINNs methodology is an elegant and flexible way to include physical knowledge in machine-learning algorithms and accelerate the approximation and accuracy when real data are used. The results and numerical experiments presented in this report should lead to not only a deep theoretical understanding (e.g. convergency and accuracy study) in the future, but also to a practical usage of PINNs framework to solve both forward and inverse physical problems from real world applications.

Key Words

physics-informed neural networks, machine learning, wave equation, boundary controllability, parameter identification

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VIELEN DANK / THANK YOU!

Erlangen. October, 2022