Professional and personal recruitment requirements for doctoral positions

We are looking for excellent, highly motivated applicants with a university degree (M.Sc./M.A./Diplom/Magister) whose scientific interests and previous knowledge match the Collaborative Research Center. Very good knowledge of English is required.

Each doctoral position is scientifically integrated into one of the research projects described below. Here, the Collaborative Research Center comprises projects with require different scientific expertise ranging from functional analysis over numerical and stochastic analysis to optimization and scientific computing.

Next we describe the specific professional and personal recruitment requirements for each research project.

Project area A: Analysis of Infinite-dimensional port-Hamiltonian systems

Project A01: Infinite-dimensional port-Hamiltonian differential-algebraic systems
Project leaders: Prof. Dr. Birgit Jacob and Prof. Dr. Timo Reis
Employer: TU Ilmenau
Short summary: The aim is to develop a comprehensive analytical theory for infinite-dimensional port-Hamiltonian differential-algebraic systems. This includes the formulation of suitable solution concepts as well as the analysis of solvability, stability and dependence on initial values and inputs. In addition, a class of nonlinear differential-algebraic gradient systems is investigated from the port-Hamiltonian perspective, and a particular application focus is on coupled electromagnetic systems, which occur in electrical engineering, e.g. in investigations into electromagnetic compatibility.
Master degree (or equivalent) in mathematics
Professional & personal requirements: Sound knowledge of systems theory and operator theory, basic knowledge of at least one of the following areas: semigroup theory, functional analysis, differential-algebraic equations.

Project A02: Port-Hamiltonian interacting particle systems: mean-field limit and control
Project leaders: Prof. Dr. Birgit Jacob and Prof. Dr. Claudia Totzeck
Employer: University of Wuppertal
Short summary: Interacting particle systems model the collective behavior of many individuals by describing only binary interactions, and therefore serve as a mathematical model for e.g. pedestrian dynamics, flocks of birds or sheep. We use the port-Hamiltonian formulation of these systems to relax the conditions for the existence of solutions and to design structure-preserving controls. We consider the particle as well as the mean-field level and link our results via a convergence analysis as the number of individuals tends to infinity.
Master degree (or equivalent) in mathematics or physics.
Professional & personal requirements: Sound knowledge of PDE analysis and basic knowledge of at least one of the following areas: continuous optimization or systems theory.

Project A03: Structural analysis of infinite-dimensional port-Hamiltonian systems with resistive ports
Project leaders: Prof. Dr. Jochen Glück and Prof. Dr. Birgit Jacob
Employer: University of Wuppertal
Short summary: Energy decay rates and control of port-Hamiltonian systems are not sufficiently understood in infinite dimensions and thus require new mathematical tools. Motivated by the geometric theory of Dirac structures we model the energy loss by a resistive element which arises from the coupling of two so-called resistive ports. The structure of this coupling can be described in the language of operator theory, which opens the door for a detailed analysis of well-posedness, decay rates, and controllability in infinite dimensions.
Master degree (or equivalent) in mathematics
Professional & personal requirements: Sound knowledge in functional analysis and operator theory, knowledge in mathematical systems theory or the analysis of partial differential equations is desirable.

Project A04: Generalized passivity-based control of bilinear port-Hamiltonian systems
Project leaders: JProf. Dr. Hannes Gernandt and Prof. Dr. Timo Reis
Employer: University of Wuppertal

Short summary: Control of networked energy systems requires an extension of the widely applied passivity-based approaches to larger classes of systems. Therefore, we develop passivity notions for bilinear and switched differential-algebraic systems. Although port-Hamiltonian systems are passive, the passivity does not incorporate the systems' dissipation explicitly and hence the relation between both notions is studied. Moreover, a theory of switched differential-algebraic port-Hamiltonian systems is developed that can be used for control design. The new control approaches are compared for switched power systems and district heating systems.
Master degree (or equivalent) in mathematics
Professional & personal requirements: Sound knowledge of systems theory and basic knowledge of at least one of the following areas: operator theory or numerical analysis, programming experience is desirable.

Project A05: Operator splitting for infinite-dimensional port-Hamiltonian systems
Project leaders: Prof. Dr. Balint Farkas and Prof. Dr. Birgit Jacob
Employer: University of Wuppertal
Short summary: Splitting methods for infinite-dimensional port-Hamiltonian systems are developed and their convergence properties are investigated. Here, the potential of splitting port-Hamiltonian systems into simpler port-Hamiltonian subsystems is exploited while the port-Hamiltonian structure is preserved. This project thus forms a solid analytical basis for numerical methods, paves the way for applications, and also establishes the (unique) solvability of the systems under consideration. One application focus is on port-Hamiltonian differential equations with delay.
Master degree (or equivalent) in mathematics or physics
Professional & personal requirements: Sound knowledge in functional analysis and operator theory, knowledge in mathematical systems theory or the analysis of partial differential equations is desirable.

Project area B: Discretization of port-Hamiltonian systems

Project B01: Goal-oriented multirate and dynamic iteration methods for port-Hamiltonian differential-algebraic systems
Project leaders: PD. Dr. Andreas Bartel and JProf. Dr. Manuel Schaller
Employer: University of Wuppertal
Short summary: The project develops new and particularly efficient time-domain methods for the simulation, control and optimization of large coupled systems. These occur particularly in complex models that combine different physical domains. The decisive advantage compared to previous methods is that energy is now (approximately) conserved. This is made possible by innovative goal-oriented approaches that include energies and powers flowing through the ports. The methods developed are tested in particular on model systems from electromagnetism.
Master degree (or equivalent) in mathematics
Professional & personal requirements: Sound knowledge in numerical analysis and basic knowledge of at least one of the following areas: optimal control, numerical linear algebra, functional analysis; programming experience required.

Project B02: Geometric numerical integration for port-Hamiltonian systems
Project leaders: Prof. Dr. Michael Günther and Prof. Dr. Nicole Marheineke
Employer: University of Trier
Short summary: With regard to ports, dissipation, and non-linear parametrizations, we develop new time integration schemes for port Hamiltonian systems of ordinary differential equations and differential-algebraic equations. The goal is to overcome existing, drastic restrictions concerning the order and thus the efficiency. The schemes are based on variants of operator splitting, which extend and generalize concepts of forced gradients, Cayley transforms and multi-rate approaches. Moreover, we consider and investigate Galerkin and discrete gradient methods particularly tailored to the port-Hamiltonian structure.
Master degree (or equivalent) in mathematics
Professional & personal requirements: Sound knowledge in numerical analysis and basic knowledge of at least one of the following areas: geometric time integration, splitting methods, differential-algebraic equations, Galerkin methods; programming experience required.

Project B03: Stochastic port-Hamiltonian models for vehicle and pedestrian dynamics
Project leaders: Prof. Dr. Barbara Rüdiger and JProf. Dr. Antoine Tordeux

Employer: University of Wuppertal
Short summary: The goals of this project are to formulate novel port-Hamiltonian models, to analyze stability and long-term behavior using the system's invariant measure, to derive limits to infinite systems, to perform simulations, and to estimate parameters using real data. By systematically addressing these aspects, this research contributes to both the advancement of traffic and pedestrian modeling and to important novel application scenarios for stochastic port-Hamiltonian systems.
Master degree (or equivalent) in mathematics, physics, informatics or engineering
Professional & personal requirements: Sound knowledge in mathematical modelling and simulation; basic knowledge in stochastic analysis, numerical methods and traffic engineering; programming experience required

Project B04: Linear solvers exploiting saddle point structure for port-Hamiltonian systems
Project leaders: Prof. Dr. Matthias Bolten and Dr. Paola Ferrari
Employer: University of Wuppertal
Short summary: Saddle point structures arise in the time integration of port-Hamiltonian systems through the coupling of different subsystems. The project utilizes this structure to develop particularly efficient linear solvers, which are especially important for simulations in high-performance computing. One focus is on multigrid methods for port-Hamiltonian systems of partial differential equations. For structured matrices that occur in discretizations on regular meshes, we strive to obtain statements about when the methods are fundamentally best possible.
Master degree (or equivalent) in mathematics or informatics
Professional & personal requirements: Sound knowledge in Numerical Analysis, knowledge in numerical linear algebra, programming experience

Project B05: Exploiting coupling and Dirac structure in numerical linear algebra kernels
Project leaders: Prof. Dr. Andreas Frommer and PD. Dr. Karsten Kahl
Employer: University of Wuppertal
Short summary: To preserve structure-induced properties of port-Hamiltonian systems like dissipativity or energy conservation, time integration methods must necessarily be implicit. The project develops iterative linear algebra kernels for the solution of the arising linear and nonlinear systems of equations which for the first time preserve these properties already at the level of each iterate and, in addition, allow for increased efficiency. Moreover, we explore the potential offered by the Dirac structure via Hodge-Laplace matrices to sidestep the inherent indefiniteness of the respective linear systems.
Master degree (or equivalent) in mathematics or informatics
Professional & personal requirements: Sound knowledge in Numerical Analysis, knowledge in numerical linear algebra are desirable, programming experience.

Project area C: Optimization with port-Hamiltonian systems

Project C01: Port-Hamiltonian methods in multi-objective shape optimization
Project leaders: Prof. Dr. Matthias Bolten, Prof. Dr. Hanno Gottschalk and Prof. Dr. Kathrin Klamroth
Employer: University of Wuppertal
Short summary: Shape optimization minimizes material resources while maintaining critical stress limits. This project improves solution methods by incorporating impulse information from port-Hamiltonian dynamics. This solves the fundamental problem of stagnation in suboptimal solutions. As a further innovative approach, the methods are adapted to multi-objective optimization problems in order to balance the competing objectives occurring in shape optimization.
Master degree (or equivalent) in mathematics or physics
Professional & personal requirements: Sound knowledge in applied mathematics demonstrated in in at least two of the fields finite element methods, functional analysis and optimization, programming experience required

Project C02: Port-Hamiltonian Systems for dynamic nonlinear network flow problems
Project leaders: Prof. Dr. Kathrin Klamroth and Prof. Dr. Claudia Totzeck
Employer: University of Wuppertal
Short summary: Precise and at the same time efficiently solvable models for dynamic network flow problems are just as relevant in supply chain design as they are for complex energy transportation problems. Typical constraints include flow conservation in the nodes, which are fulfilled by definition by port-Hamiltonian systems

on graphs. In combination with optimal control approaches, we develop and analyze a model hierarchy of dynamic and nonlinear network flow problems and exploit coupling properties of port-Hamiltonian systems to efficiently solve medium to large-scale problems.

Master degree (or equivalent) in mathematics or comparable

Professional & personal requirements: Sound knowledge in network optimization or optimal control, programming experience required

Project C03: Data-driven surrogate modelling for differential-algebraic port-Hamiltonian systems

Project leaders: Prof. Dr. Michael Günther and Prof. Dr. Peter Zaspel

Employer: University of Wuppertal

Short summary: Gaussian processes as port-Hamiltonian surrogate models make it possible to treat nonlinear Hamiltonian or effort functions in port-Hamiltonian differential equations, even and especially if they are not explicitly known. The project investigates how such surrogate models can be constructed from measured and synthetic data. A decisive advantage is that existing gaps in coupled port-Hamiltonian systems can be closed in a structure-preserving manner.

Master degree (or equivalent) in mathematics, computer science, physics, or related fields

Professional & personal requirements: Sound knowledge in (scientific) machine learning, and knowledge in numerical analysis and numerical linear algebra are expected. Knowledge in parallel programming is desirable. Prior knowledge in differential-algebraic equations, Gaussian processes or kernel based methods is a plus; programming experience in Python or C/C++ is expected.

Project C06: Port-Hamiltonian methods for optimal control of large-scale systems

Project leaders: JProf. Dr. Hannes Gernandt and JProf. Dr. Manuel Schaller

Employer: TU Chemnitz

Short summary: We investigate the previously unnoticed port-Hamiltonian structure of iterative numerical solvers of large optimal control problems. Based on this, optimization-based controllers are formulated in which the iterative solver of the optimal control problem is coupled with a system to be controlled. The decisive advantage of this new approach is that the inherent dissipativity of port-Hamiltonian systems guarantees the stability of the closed control loop, especially if, for example, learning-based surrogate models are used in the optimal control problem.

Master degree (or equivalent) in mathematics

Professional & personal requirements: Sound knowledge in optimal control, and infinite-dimensional system theory, basic knowledge in numerical methods, programming experience required.