Hydrodynamics studies of cyclic voltammetry for electrochemical micro biosensors

We investigate the effect of flow rate on the electrical current response to the applied voltage in a micro electrochemical system. To accomplish this, we considered an ion-transport model that is governed by the Nernst-Planck equation coupled to the Navier-Stokes equations for hydrodynamics. The Butler-Volmer relation provides the boundary conditions, which represent reaction kinetics at the electrode-electrolyte interface. The result shows that convection drastically affects the rate of surface kinetics. At a physically sufficient high flow rates and lower scan rates, the current response is limited by the convection due to fresh ions being brought to the electrode surface and immediately taken away before any surface reaction. However, at high flow and scan rates, the Faradaic current overrides current due to convection. The model also allows predicting the effect of varying electrolyte concentration and scan rates respectively.

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- Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Micro- and Nanotechnology, Bioanalytics, Nanoprobes, Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics
- Authors: Adesokan, B. J. (Intern), Quan, X. (Intern), Evgrafov, A. (Intern), Heiskanen, A. (Intern), Boisen, A. (Intern)
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  - Scopus rating (2016): CiteScore 0.45 SJR 0.24 SNIP 0.383
  - Web of Science (2016): Indexed yes
  - BFI (2015): BFI-level 1
The PhD dissertation is concerned with mathematical modeling and simulation of electrochemical systems. The first three chapters of the thesis consist of the introductory part, the model development chapter and the chapter on the summary of the main results. The remaining three chapters report three independent papers and manuscripts.

As a preliminary to the study, we describe a general model for electrochemical systems and study their underlying mechanisms through electroanalytical techniques. We then extend the model to a more realistic model for microelectrochemical systems which incorporates the finite size of ionic species in the transport equation. The model presents a more appropriate boundary conditions which describe the modified Butler-Volmer reaction kinetics and account for the surface capacitance of the thin electric double layer. We also have found analytical solution for the reactants in the bulk electrolyte that are traveling waves.

The first paper presents the mathematical model which describes an electrochemical system and simulates an electroanalytical technique called cyclic voltammetry. The model is governed by a system of advection–diffusion equations with a nonlinear reaction term at the boundary. We investigate the effect of flow rates, scan rates, and concentration on the cyclic voltammetry. We establish that high flow rates lead to the reduced hysteresis in the cyclic voltammetry curves and increasing scan rates lead to more pronounced current peaks. The final part of the paper shows that the response current in a cyclic voltammetry increases proportionally to the electrolyte concentration.

In the second paper we present an experiment of an electrochemical system in a microfluidic system and compare the...
result to the numerical solutions. We investigate how the position of the electrodes in the system affects the recorded cyclic voltammetry. The result shows that convection influences the charge transfer dynamics on the electrode surface and hence the cyclic voltammetry recorded. In terms of relative high flow to scan rates, the current response is dominated by the convection due to the fresh supply of reactants towards the electrode surface and quick removal of the products. We also establish that at high scan rates and modest flow rates, peak currents are recorded. Finally, the results show that the position of the electrodes is critical when performing cyclic voltammetry under the flow condition. The numerical results show promising agreement with experimental findings which could be critical in designing highly sensitive electrochemical systems.

The last paper explores the numerical solution which describes the non-linear transient responses to a large applied potential at the electrode in a microelectrochemical system. In our analysis, we account for the finite size properties of ions in the mass and the charge transport of ionic species in an electrochemical system. This term characterizes the saturation of the ionic species close to the electrode surface. We then analyse the responses of the system on the charging of the electric double layer. We consider an arbitrary electrolyte solution that is sandwiched between electrodes and allow for electrochemical reactions at the electrode/electrolyte interface. One of the electrodes is biased with a potential which triggers the reaction and the dynamics of the system. We establish that there is a quick build up of boundary layers in the double layer, but the finite size constraint on the ionic species prevents overcrowding of the ionic species. The result also shows that reactants which undergo charge transfer at the electrode/electrolyte interface crowded the electric double layer and the dynamics of the electric double layer is controlled by the charge transfer.

**General information**

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**Organisations:** Department of Applied Mathematics and Computer Science, Dynamical Systems, Scientific Computing

**Authors:** Adesokan, B. J. (Intern), Evgrafov, A. (Intern), Sørensen, M. P. (Intern)

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**Simulating cyclic voltammetry under advection for electrochemical cantilevers**

We present a mathematical model describing an electrochemical system involving electrode–electrolyte interaction. The model is governed by a system of advection–diffusion equations with a nonlinear reaction term at the boundary. Our calculations based on such model demonstrate the dynamics of ionic currents in the electrolyte. The model allows us to predict the effect of varying flow rates, scan rates, and electrolyte concentration of the electrochemical system.

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**Organisations:** Department of Applied Mathematics and Computer Science, Dynamical Systems, Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics

**Authors:** Adesokan, B. J. (Intern), Evgrafov, A. (Intern), Sørensen, M. P. (Intern)

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Iso-geometric shape optimization of magnetic density separators

Purpose
The waste recycling industry increasingly relies on magnetic density separators. These devices generate an upward magnetic force in ferro-fluids allowing to separate the immersed particles according to their mass density. Recently, a new separator design has been proposed that significantly reduces the required amount of permanent magnet material. The purpose of this paper is to alleviate the undesired end-effects in this design by altering the shape of the ferromagnetic covers of the individual poles.

Design/methodology/approach
The paper represents the shape of the ferromagnetic pole covers with B-splines and defines a cost functional that measures the non-uniformity of the magnetic field in an area above the poles. The authors apply an iso-geometric shape optimization procedure, which allows us to accurately represent, analyze and optimize the geometry using only a few design variables. The design problem is regularized by imposing constraints that enforce the convexity of the pole cover shapes and is solved by a non-linear optimization procedure. The paper validates the implementation of the algorithm using a simplified variant of the design problem with a known analytical solution. The algorithm is subsequently applied to the problem posed.

Findings
The shape optimization attains its target and yields pole cover shapes that give rise to a magnetic field that is uniform over a larger domain.
Research limitations/implications
This increased magnetic field uniformity is obtained at the cost of a pole cover shape that differs per pole. This limitation has negligible impact on the manufacturing of the separator. The new pole cover shapes therefore lead to improved performance of the density separation.

Practical implications
Due to the larger uniformity the generated field, these shapes should enable larger amounts of waste to be processed than the previous design.

Originality/value
This paper treats the shapes optimization of magnetic density separators systematically and presents new shapes for the ferromagnetic poles covers.

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Authors: Dang Manh, N. (Ekstern), Evgrafov, A. (Intern), Gravesen, J. (Intern), Lahaye, D. (Ekstern)
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Mathematical Modeling and Dimension Reduction in Dynamical Systems

Processes that change in time are in mathematics typically described by differential equations. These may be applied to model everything from weather forecasting, brain patterns, reaction kinetics, water waves, finance, social dynamics, structural dynamics and electrodynamics to name only a few. These systems are generically nonlinear and the studies of them often become enormously complex. The framework in which such systems are best understood is via the theory of dynamical systems, where the critical behavior is systematically analyzed by performing bifurcation theory. In that context the current thesis is attacking two problems.

The first is concerned with the mathematical modelling and analysis of an experiment of a vibro-impacting beam. This type of dynamical system has received much attention in the recent years and they occur frequently in mechanical applications, where they induce noise and wear which decrease the life time of machines. From the modelling point of view these systems are often particularly rich in nonlinear dynamics. In the present study a mathematical model is derived. Amongst other outcomes the model was successfully applied to predict a nonlinear phenomenon, namely the existence of isolas of subharmonic orbits. These were then verified in the practical experiment in the lab. The second problem that is addressed in the current thesis is a problem that has developed as a consequence of the increasing power of computers which has created the demand for analysis of ever more advanced and complex systems. These complex systems are computationally very demanding and proper analysis of the qualitative behavior of the systems becomes difficult. In general it is not possible to construct bifurcation diagrams for these so-called high-dimensional models efficiently. In order to overcome this obstacle much research is going into the direction of development of robust methods to perform dimension and model reduction such as to pave the way for a qualitative analysis of the high-dimensional problems by analyzing the low-dimensional models.

In this thesis we demonstrate how to reduce the dimension of a certain class of dynamical systems by construction of k-dimensional submanifolds using the so-called graph transform. The method is suitable for a specific class of problems with spectral gaps, these are often observed. In particular the method is applied to a mechanical system. Furthermore the method has some unique and promising properties compared to other methods.

Planar Parametrization in Isogeometric Analysis

Before isogeometric analysis can be applied to solving a partial differential equation posed over some physical domain, one needs to construct a valid parametrization of the geometry. The accuracy of the analysis is affected by the quality of the parametrization. The challenge of computing and maintaining a valid geometry parametrization is particularly relevant in applications of isogeometric analysis to shape optimization, where the geometry varies from one optimization iteration to another. We propose a general framework for handling the geometry parametrization in isogeometric analysis and shape optimization. It utilizes an expensive non-linear method for constructing/updating a high quality reference parametrization, and an inexpensive linear method for maintaining the parametrization in the vicinity of the reference one. We describe several linear and non-linear parametrization methods, which are suitable for our framework. The non-linear methods we consider are based on solving a constrained optimization problem numerically, and are divided into two classes, geometry-oriented methods and analysis-oriented methods. Their performance is illustrated through a few numerical examples.
State space Newton's method for topology optimization

We introduce a new algorithm for solving certain classes of topology optimization problems, which enjoys fast local convergence normally achieved by the full space methods while working in a smaller reduced space. The computational complexity of Newton's direction finding subproblem in the algorithm is comparable with that of finding the steepest descent direction in the traditional first order nested/reduced space algorithms for topology optimization. That is, the space reduction is computationally inexpensive, and more importantly it does not ruin the sparsity of the full-space system of optimality conditions.

The fast local convergence of the algorithm allows one to efficiently solve a sequence of optimization problems for varying parameters (numerical continuation). This can be utilized for eliminating the errors introduced by the approximate enforcement of the boundary conditions or 0/1-type constraints on the design field through penalties in many topology optimization approaches.

We test the algorithm on the benchmark problems of dissipated power minimization for Stokes flows, and in all cases the algorithm outperforms the traditional first order reduced space/nested approaches by a factor varying from two to almost twenty in terms of the number of iterations while attaining an almost unprecedented accuracy in solving the discretized topology optimization problem. Finally we present a few extensions to the algorithm, one involving computations on adaptively refined meshes and another related to solving topology optimization problems for non-Newtonian fluids.

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State-Space Reduced Newton's Algorithm for Topology Optimization

In the topology optimization community it is customary to formulate the optimization problem in terms of the design variables only—this is a basis for a so-called nested approach. Such formulations foster numerical algorithms operating in the design space only, which has a significantly smaller dimensionality than the full (design times state times adjoint state) space of the problem. On the flip side, the function/derivative evaluations in this framework are very expensive, as they
require solving the governing/adjoint partial differential equations. Even more importantly, it is impractical to use the
Newton’s iteration in this space. Indeed, the dimensionality of the design space is still very large for the topology
optimization problems, yet the reduced Hessian matrix is fully populated and is exceedingly expensive to compute.
An alternative approach is to formulate and solve the problem in the full space. By significantly increasing the
dimensionality of the space one ends up with inexpensive function/derivative evaluations and preserves the sparsity of the
discretizations of the governing equations, which act as equality constraints in the resulting optimization problem. We
propose a third alternative, which is based on reducing the optimal design problem onto the state space. Indeed, in certain
topology optimization problems encountered in practice, the design space has a very simple structure. This allows us to
eliminate the design variables from the problem with tiny computational effort and without destroying the sparsity of
the problem. Therefore the resulting optimization algorithm operates in somewhat smaller space (when compared to the full
space) while maintaining the inexpensiveness of the function evaluations enjoyed by the full space methods and the
possibility of utilizing the Newton’s algorithm due to the preserved sparsity.

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Organisations: Norwegian University of Science and Technology
Authors: Evgrafov, A. (Intern)
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Source: PublicationPreSubmission
Source-ID: 100817470
Publication: Research - peer-review › Article in proceedings – Annual report year: 2014

**Introduction to Continuous Optimization**
Optimization, or mathematical programming, is a fundamental subject within decision science and operations research, in
which mathematical decision models are constructed, analyzed, and solved.

The book’s focus lies on providing a basis for the analysis of optimization models and of candidate optimal solutions for
continuous optimization models. The main part of the mathematical material therefore concerns the analysis and linear
algebra that underlie the workings of convexity and duality, and necessary/sufficient local/global optimality conditions for
continuous optimization problems. Natural algorithms are then developed from these optimality conditions, and their most
important convergence characteristics are analyzed. The book answers many more questions of the form “Why?” and
“Why not?” than “How?”. We use only elementary mathematics in the development of the book, yet are rigorous
throughout.

The book provides lecture, exercise and reading material for a first course on continuous optimization and mathematical
programming, geared towards third-year students, and has already been used as such for nearly ten years. The preface to
the second edition describes the main changes made since the first, 2005, edition.

The book can be used in mathematical optimization courses at any mathematics, engineering, economics, and business
schools. It is a perfect starting book for anyone who wishes to develop his/her understanding of the subject of optimization,
before actually applying it.

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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing
Authors: Andreasson, N. (Ekstern), Evgrafov, A. (Intern), Patriksson, M. (Ekstern), Gustavsson, E. (Ekstern), Önnheim, M.
(Ekstern)
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Newton-type method for the variational discretization of topology optimization problems
We present a locally quadratically convergent optimization algorithm for solving topology optimization problems. The distinguishing feature of the algorithm is to treat the design as a smooth function of the state and not vice versa as in the traditional nested approach to topology optimization, which we achieve by inverting a part of perturbed optimality conditions for the problem. In this way, the computational bottleneck is conveniently shifted from evaluating the merit function to a direction finding subproblem. The latter involves solving certain linearized PDEs, and the computational effort is similar to that of finding a gradient of the merit function in the traditional nested approach. We illustrate the performance of the algorithm on benchmark topology optimized problems in fluid mechanics.

Control in the coefficients with variational crimes: Application to topology optimization of Kirchhoff plates
We study convergence of discontinuous Galerkin-type discretizations of the problems of control in the coefficients of uniformly elliptic partial differential equations (PDEs). As a model problem we use that of the optimal design of thin (Kirchhoff) plates, where the governing equations are of the fourth order. Methods which do not require approximation subspaces to conform to the smoothness requirements dictated by the PDE are very attractive for such problems. However, variational formulations of such methods normally contain boundary integrals whose dependence on the small, with respect to “volumetric” Lebesgue norm, changes of the coefficients is generally speaking not continuous. We utilize the lifting formulation of the discontinuous Galerkin method to deal with this issue. Our main result is that limit points of sequences of designs verifying discrete versions of stationarity can also be expected to satisfy stationarity for the limiting continuum mechanics problem. We illustrate the practical behaviour of our discretization strategy on some benchmark-type examples.
In this thesis a recently proposed numerical method for solving partial differential equations, isogeometric analysis (IGA), is utilized for the purpose of shape optimization, with a particular emphasis on applications to two-dimensional design problems arising in electromagnetic applications. The study is motivated by the fact that in contrast with most commonly utilized finite element approximations, IGA allows one to exactly represent geometries arising in computer aided design applications with relatively few variables using splines. The following problems coming from theoretical considerations or engineering applications are solved in the thesis utilizing IGA: finding a shape having a few prescribed eigenvalues of the Laplace operator; shape optimization of sub-wavelength micro-antennas for energy concentration; shape optimization of nano-antennas for field enhancement; economical design of magnetic density separators. From the point of view of method development, several heuristic approaches for extending a valid parametrization of the boundary onto the domain's interior are examined in the thesis. The parametrization approaches and a method for validating a spline parametrization are combined into an iterative algorithm for shape optimization of two dimensional electromagnetic
problems. The algorithm may also be relevant for problems in other engineering disciplines. Using the methods developed in this thesis, remarkably we have obtained antennas that perform one million times better than an earlier topology optimization result. This shows a great potential of shape optimization using IGA in the area of electromagnetic antenna design in particular, and for electromagnetic

ISOGEOMETRIC SHAPE OPTIMIZATION FOR ELECTROMAGNETIC SCATTERING PROBLEMS
We consider the benchmark problem of magnetic energy density enhancement in a small spatial region by varying the shape of two symmetric conducting scatterers. We view this problem as a prototype for a wide variety of geometric design problems in electromagnetic applications. Our approach for solving this problem is based on shape optimization and isogeometric analysis. One of the major difficulties we face to make these methods work together is the need to maintain a valid parametrization of the computational domain during the optimization. Our approach to generating a domain parametrization is based on minimizing a second order approximation to the Winslow functional in the vicinity of a reference parametrization. Furthermore, we enforce the validity of the parametrization by ensuring the non-negativity of the coefficients of a B-spline expansion of the Jacobian. The shape found by this approach outperforms earlier design computed using topology optimization by a factor of one billion

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ISIGEOMETRIC SHAPE OPTIMIZATION FOR ELECTROMAGNETIC SCATTERING PROBLEMS
We consider the benchmark problem of magnetic energy density enhancement in a small spatial region by varying the shape of two symmetric conducting scatterers. We view this problem as a prototype for a wide variety of geometric design problems in electromagnetic applications. Our approach for solving this problem is based on shape optimization and isogeometric analysis. One of the major difficulties we face to make these methods work together is the need to maintain a valid parametrization of the computational domain during the optimization. Our approach to generating a domain parametrization is based on minimizing a second order approximation to the Winslow functional in the vicinity of a reference parametrization. Furthermore, we enforce the validity of the parametrization by ensuring the non-negativity of the coefficients of a B-spline expansion of the Jacobian. The shape found by this approach outperforms earlier design computed using topology optimization by a factor of one billion

General information
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BFI (2013): BFI-level 1
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.526 SNIP 1.142 CiteScore 1.69
We present a convergence analysis of a cell-based finite volume (FV) discretization scheme applied to a problem of control in the coefficients of a generalized Laplace equation modelling, for example, a steady state heat conduction. Such problems arise in applications dealing with geometric optimal design, in particular shape and topology optimization, and are most often solved numerically utilizing a finite element approach. Within the FV framework for control in the coefficients problems the main difficulty we face is the need to analyze the convergence of fluxes defined on the faces of cells, whereas the convergence of the coefficients happens only with respect to the "volumetric" Lebesgue measure. Additionally, depending on whether the stationarity conditions are stated for the discretized or the original continuous problem, two distinct concepts of stationarity at a discrete level arise. We provide characterizations of limit points, with respect to FV mesh size, of globally optimal solutions and two types of stationary points to the discretized problems. We illustrate the practical behaviour of our cell-based FV discretization algorithm on a numerical example.
Finite Volumes Discretization of Topology Optimization Problems

Utilizing control in the coefficients of partial differential equations (PDEs) for the purpose of optimal design, or topology optimization, is a well established technique in both academia and industry. Advantages of using control in the coefficients for optimal design purposes include the flexibility of the induced parametrization of the design space that allows optimization algorithms to efficiently explore it, and the ease of integration with existing computational codes in a variety of application areas, the simplicity and efficiency of sensitivity analyses|all stemming from the use of the same grid throughout the optimization procedure. As topology optimization is gaining maturity, the method is applied to increasingly more complex coupled multi-physical problems. As a result it becomes vital to utilize robust and mature PDE solvers within a topology optimization framework. Finite volume methods (FVMs) represent such a mature and versatile technique for discretizing partial differential equations in the form of conservation laws of varying types. Advantages of FVMs include the simplicity of implementation, their local conservation properties, and the ease of coupling various PDEs in a multi-physics setting. In fact, FVMs represent a standard method of discretization within engineering communities dealing with computational fluid dynamics, transport, and convection-reaction problems. Among various avours of FVMs, cell based approaches, where all variables are associated only with cell centers, are particularly attractive, as all involved PDEs on a given domain are discretized using the same and the lowest possible number of degrees of freedom. In spite of their numerous favourable advantages, FVMs have seen very little adoption within the topology optimization community, where the absolute majority of numerical computations is done using finite element methods (FEMs). Despite some limited recent eorts [1, 2], we have only started to develop our understanding of the interplay between the control in the coefficients and FVMs. Recent advances in discrete functional analysis allow us to analyze convergence of FVM discretizations of model topology optimization problems. We illustrate the numerical behaviour of a cell based FVM topology optimization algorithm on a series of benchmark examples.
Isogeometric Analysis and Shape Optimisation
One of the attractive features of isogeometric analysis is the exact representation of the geometry. The geometry is furthermore given by a relative low number of control points and this makes isogeometric analysis an ideal basis for shape optimisation. I will describe some of the results we have obtained and also some of the problems we have encountered. One of these problems is that the geometry of the shape is given by the boundary alone. And, it is the parametrisation of the boundary which is changed by the optimisation procedure. But isogeometric analysis requires a parametrisation of the whole domain. So in every optimisation cycle we need to extend a parametrisation of the boundary of a domain to the whole domain. It has to be fast in order not to slow the optimisation down but it also has to be robust and give a parametrisation of high quality. These are conflicting requirements so we propose the following approach. During the optimisation a fast linear method is used, but if the parametrisation becomes singular or close to singular then the optimisation is stopped and the parametrisation is improved using a nonlinear method. The optimisation then continues using a linear method. We will explain how the validity of a parametrisation can be checked and we will describe various ways to parametrise a domain. We will in particular study the Winslow functional which turns out to have some desirable properties. Other problems we touch upon is clustering of boundary control points (design variables) and self intersection of the design. The first problem can be solves by a suitable regularisation and the latter by a method that resembles how the validity of the parametrisation is secured.

General information
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Organisations: Geometry, Department of Mathematics, Applied functional analysis, Department of Mechanical Engineering
Authors: Gravesen, J. (Intern), Evgrafov, A. (Intern), Gersborg, A. R. (Intern), Nguyen, D. M. (Intern), Nielsen, P. N. (Intern)
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http://www.usnccm.org/
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Isogeometric Shape Optimization of Vibrating Membranes
We consider a model problem of isogeometric shape optimization of vibrating membranes whose shapes are allowed to vary freely. The main obstacle we face is the need for robust and inexpensive extension of a B-spline parametrization from the boundary of a domain onto its interior, a task which has to be performed in every optimization iteration. We experiment with two numerical methods (one is based on the idea of constructing a quasi-conformal mapping, whereas the other is based on a spring-based mesh model) for carrying out this task, which turn out to work sufficiently well in the present situation. We perform a number of numerical experiments with our isogeometric shape optimization algorithm and present smooth, optimized membrane shapes. Our conclusion is that isogeometric analysis fits well with shape optimization.

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On the sensitivities of multiple eigenvalues

We consider the generalized symmetric eigenvalue problem where matrices depend smoothly on a parameter. It is well known that in general individual eigenvalues, when sorted in accordance with the usual ordering on the real line, do not depend smoothly on the parameter. Nevertheless, symmetric polynomials of a number of eigenvalues, regardless of their
multiplicity, which are known to be isolated from the rest depend smoothly on the parameter. We present explicit readily computable expressions for their first derivatives. Finally, we demonstrate the utility of our approach on a problem of finding a shape of a vibrating membrane with a smallest perimeter and with prescribed four lowest eigenvalues, only two of which have algebraic multiplicity one.

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Web of Science (2014): Indexed yes
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Scopus rating (2013): CiteScore 2.86
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.08
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 1.85
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Web of Science (2008): Indexed yes
Web of Science (2007): Indexed yes
Web of Science (2006): Indexed yes
Web of Science (2005): Indexed yes
Web of Science (2004): Indexed yes
Web of Science (2003): Indexed yes
Web of Science (2002): Indexed yes
Web of Science (2001): Indexed yes
Web of Science (2000): Indexed yes
Topology Optimization of Nano-Mechanical Cantilever Sensors Using a C0 Discontinuous Galerkin-Type Approach

We demonstrate the use of a C0 discontinuous Galerkin method for topology optimization of nano-mechanical sensors, namely temperature, surface stress, and mass sensors. The sensors are modeled using classical thin plate theory, which requires C1 basis functions in the standard finite element method. A discontinuous Galerkin type approach allows the use of C0 basis functions or any common basis functions, e.g. based on Lagrange elements. Thus the implementation is simple and requires fewer degrees of freedom per element compared to common finite element implementation of plate problems.

General information
State: Published
Organisations: Department of Mathematics, Applied functional analysis, Dynamical systems
Authors: Marhadi, K. S. (Intern), Evgrafov, A. (Intern), Sørensen, M. P. (Intern)
Publication date: 2011

Host publication information
Title of host publication: Proceedings of the 9th World Congress on Structural and Multidisciplinary Optimization
Main Research Area: Technical/natural sciences
Conference: 9th World Congress on Structural and Multidisciplinary Optimization, Shizuoka, Japan, 13/06/2011 - 13/06/2011
Thin plates, Topology optimization, Nano-mechanical sensors, Discontinuous Galerkin method
Links:
http://www.wcsmo9.com/
Source: orbit
Source-ID: 279726
Publication: Research - peer-review › Article in proceedings – Annual report year: 2011

Topology optimization problems with design-dependent sets of constraints

Topology optimization is a design tool which is used in numerous fields. It can be used whenever the design is driven by weight and strength considerations. The basic concept of topology optimization is the interpretation of partial differential equation coefficients as effective material properties and designing through changing these coefficients. For example, consider a continuous structure. Then the basic concept is to represent this structure by small pieces of material that are coinciding with the elements of a finite element model of the structure. This thesis treats stress constrained structural topology optimization problems. For such problems a stress constraint for an element should only be present in the optimization problem when the structural design variable corresponding to this element has a value greater than zero. We model the stress constrained topology optimization problem using both discrete and continuous design variables. Using discrete design variables is the natural modeling frame. However, we cannot solve real-size problems with the technological limits of today. Using continuous design variables makes it possible to also study topology optimization problems of large scale. We find the global optimal solution to the stress constrained topology optimization problem using discrete design variables. The problem is solved using a parallel cut-and-branch method. The cuts include information about the mathematical structure of our problems and also their physics. The method shows particularly good speedup because of the added cuts. The study of stress constrained topology optimization problem using continuous design variables constitute the main part of this thesis. Primarily we study the problem reformulated into standard form via the Mathematical Program with Equilibrium Constraints (MPEC) formulations. We look at the two variations: Mathematical Program with Complementarity Constraints and Mathematical Program with Vanishing Constraints. These problem formulations are compared to a restricted problem formulation. The restricted problem include stress constraints for all elements independently of the values of the design variables. The investigations include validating constraint qualifications, attacking the problem formulations directly, and bounding the objective function value. We consider different constraint qualifications and whether they hold for the MPEC formulations of some truss topology optimization problems. We provide examples in which none of the considered constraint qualifications hold at the optimal solutions. This occurs when the upper limits of the design variables become active and there are nodal displacements that are non-unique. Note that this situation is generally the case at an optimal solution. However, the numerical experiments show that the MPEC formulations are not less robust than the restricted problem formulation. This indicates that the inherent lack of constraint qualifications is not the main numerical obstacle. We further observe that a general nonlinear interior-point algorithm applied to the MPEC formulations outperforms a general nonlinear active-set sequential quadratic programming method. Inspired by this, we implement an interior-point algorithm such that we have full control of all aspects of the code. Solving
the stress constrained structural topology optimization problem is computationally challenging. We therefore present a
technique that decides whether it may pay-off to actually treat the stress constrained problem. The technique finds lower
and upper bounds on the objective function value of the stress constrained topology optimization problem. It further
produces a feasible design. If the upper and lower bounds are far apart, then one should invest in attacking the stress
constrained structural topology optimization problem. Otherwise one can use the obtained feasible design.

A parametric level-set approach for topology optimization of flow domains
Traditional methods based on an element-wise parameterization of the material distribution applied to the topology
optimization of fluidic systems often suffer from slow convergence of the optimization process, as well as robustness
issues at increased Reynolds numbers. The local influence of the design variables in the traditional approaches is seen as
a possible cause for the slow convergence. Non-smooth material distributions are suspected to trigger premature onset of
instantaneous flows which cannot be treated by steady-state flow models. In the present work, we study whether the
convergence and the versatility of topology optimization methods for fluidic systems can be improved by employing a
parametric level-set description. In general, level-set methods allow controlling the smoothness of boundaries, yield a non-
local influence of design variables, and decouple the material description from the flow field discretization. The parametric
level-set method used in this study utilizes a material distribution approach to represent flow boundaries, resulting in a
non-trivial mapping between design variables and local material properties. Using a hydrodynamic lattice Boltzmann
method, we study the performance of our level-set approach in comparison to a traditional material distribution approach.
By numerical examples, the parametric level-set approach is validated through comparison with traditional material
distribution based methods. While the parametric level-set approach leads to similar optimal designs, the present study
reveals no general improvements of the convergence of the optimization process and of the robustness of the nonlinear
flow analyses when compared to the traditional material distribution approach. Instead, our numerical experiment suggests
that a continuation method operating on the volume constraint is needed to achieve optimal designs at higher Reynolds
numbers.

A parametric level-set approach for topology optimization of flow domains
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method, we study the performance of our level-set approach in comparison to a traditional material distribution approach.
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flow analyses when compared to the traditional material distribution approach. Instead, our numerical experiment suggests
that a continuation method operating on the volume constraint is needed to achieve optimal designs at higher Reynolds
numbers.

A parametric level-set approach for topology optimization of flow domains
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optimization of fluidic systems often suffer from slow convergence of the optimization process, as well as robustness
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instantaneous flows which cannot be treated by steady-state flow models. In the present work, we study whether the
convergence and the versatility of topology optimization methods for fluidic systems can be improved by employing a
parametric level-set description. In general, level-set methods allow controlling the smoothness of boundaries, yield a non-
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level-set method used in this study utilizes a material distribution approach to represent flow boundaries, resulting in a
non-trivial mapping between design variables and local material properties. Using a hydrodynamic lattice Boltzmann
method, we study the performance of our level-set approach in comparison to a traditional material distribution approach.
By numerical examples, the parametric level-set approach is validated through comparison with traditional material
distribution based methods. While the parametric level-set approach leads to similar optimal designs, the present study
reveals no general improvements of the convergence of the optimization process and of the robustness of the nonlinear
flow analyses when compared to the traditional material distribution approach. Instead, our numerical experiment suggests
that a continuation method operating on the volume constraint is needed to achieve optimal designs at higher Reynolds
numbers.
Cell based finite volume discretization of control in the coefficients problems

General information
State: Published
Organisations: Applied functional analysis, Department of Mathematics, Dynamical systems
Authors: Evgrafov, A. (Intern), Gregersen, M. M. (Intern), Sørensen, M. P. (Intern)
Pages: 306-309
Publication date: 2010

Host publication information
Title of host publication: Nordic Seminar on Computational Mechanics
Place of publication: Stockholm, Sweden
Publisher: KTH Mechanics
Editor: Eriksson, A.
Main Research Area: Technical/natural sciences
Conference: 23rd Nordic Seminar on Computational Mechanics, Stockholm, Sweden, 21/10/2010 - 21/10/2010
Source: orbit
Isogeometric analysis and shape optimisation

General information
State: Published
Organisations: Geometry, Department of Mathematics, Applied functional analysis, Department of Mechanical Engineering
Authors: Gravesen, J. (Intern), Evgrafov, A. (Intern), Gersborg, A. R. (Intern), Nguyen, D. M. (Intern), Nielsen, P. N. (Intern)
Pages: 14-17
Publication date: 2010

Host publication information
Title of host publication: Proceeedings of NSCM-23
Editors: Erikson, A., Tibert, G.
Main Research Area: Technical/natural sciences
Conference: 23rd Nordic Seminar on Computational Mechanics, Stockholm, Sweden, 21/10/2010 - 21/10/2010
Source: orbit
Source-ID: 268625
Publication: Research › Article in proceedings – Annual report year: 2010

Isogeometric Analysis Towards Shape Optimization in Electromagnetics

General information
State: Published
Organisations: Geometry, Department of Mathematics, Applied functional analysis, Department of Mechanical Engineering, Solid Mechanics
Authors: Nguyen, D. M. (Intern), Evgrafov, A. (Intern), Gravesen, J. (Intern), Jensen, J. S. (Intern)
Number of pages: 348
Pages: 18-21
Publication date: 2010

Host publication information
Title of host publication: Proceeedings of NSCM-23, the 23rd Nordic Seminar on Computational Mechanics
Place of publication: Stockholm
Main Research Area: Technical/natural sciences
Conference: 23rd Nordic Seminar on Computational Mechanics, Stockholm, Sweden, 21/10/2010 - 21/10/2010
Source: orbit
Source-ID: 271881
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

Isogeometric Design of Vibrating Membranes

General information
State: Published
Organisations: Geometry, Department of Mathematics, Department of Mechanical Engineering
Authors: Nguyen, D. M. (Intern), Evgrafov, A. (Intern), Gersborg, A. R. (Intern), Gravesen, J. (Intern)
Publication date: 2010

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 272282
Publication: Research › Sound/Visual production (digital) – Annual report year: 2010

Isogeometric Shape Optimization

General information
State: Published
Organisations: Department of Mathematics, Department of Mechanical Engineering
Authors: Nielsen, P. N. (Intern), Nguyen, D. M. (Intern), Evgrafov, A. (Intern), Gersborg, A. R. (Intern), Gravesen, J. (Intern)
Isogeometric Shape Optimization of freely varying shapes

General information
State: Published
Organisations: Geometry, Department of Mathematics, Applied functional analysis, Department of Mechanical Engineering
Authors: Nguyen, D. M. (Intern), Evgrafov, A. (Intern), Gersborg, A. R. (Intern), Gravesen, J. (Intern)
Publication date: 2010
Event: Abstract from 9th World Congress on Computational Mechanics and 4th Asian Pacific Congress on Computational Mechanics, Sydney, Australia.
Main Research Area: Technical/natural sciences
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Source-ID: 272284
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2010

Isogeometric Shape Optimization of Vibrating Membranes

General information
State: Published
Organisations: Geometry, Department of Mathematics, Applied functional analysis, Department of Mechanical Engineering
Authors: Nguyen, D. M. (Intern), Evgrafov, A. (Intern), Gersborg, A. R. (Intern), Gravesen, J. (Intern)
Publication date: 2010

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Title of host publication: ECCM 2010
Main Research Area: Technical/natural sciences
Conference: 4th European Conference on Computational Mechanics, Paris, France, 16/05/2010 - 16/05/2010
Source: orbit
Source-ID: 275472
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

Topology optimization of flexible micro-fluidic devices
A multi-objective topology optimization formulation for the design of dynamically tunable fluidic devices is presented. The flow is manipulated via external and internal mechanical actuation, leading to elastic deformations of flow channels. The design objectives characterize the performance in the undeformed and deformed configurations. The layout of fluid channels is determined by material topology optimization. In addition, the thickness distribution, the distribution of active material for internal actuation, and the support conditions are optimized. The coupled fluid-structure response is predicted by a non-linear finite element model and a hydrodynamic lattice Boltzmann method. Focusing on applications with low flow velocities and pressures, structural deformations due to fluid-forces are neglected. A mapping scheme is presented that couples the material distributions in the structural and fluid mesh. The governing and the adjoint equations of the resulting fluid-structure interaction problem are derived. The proposed method is illustrated with the design of tunable manifolds.
Adjoint Parameter Sensitivity Analysis for the Hydrodynamic Lattice Boltzmann Method with Applications to Design Optimization

We present an adjoint parameter sensitivity analysis formulation and solution strategy for the lattice Boltzmann method (LBM). The focus is on design optimization applications, in particular topology optimization. The lattice Boltzmann method is briefly described with an in-depth discussion of solid boundary conditions. We show that a porosity model is ideally suited for topology optimization purposes and models no-slip boundary conditions with sufficient accuracy when compared to interpolation bounce-back conditions. Augmenting the porous boundary condition with a shaping factor, we define a generalized geometry optimization formulation and derive the corresponding sensitivity analysis for the single relaxation LBM for both topology and shape optimization applications. Using numerical examples, we verify the accuracy of the analytical sensitivity analysis through a comparison with finite differences. In addition, we show that for fluidic topology optimization a scaled volume constraint should be used to obtain the desired "0-1" optimal solutions. (C) 2008 Elsevier Ltd. All rights reserved.
Design of deformation-sensitive flow problems by topology optimization

**General information**
State: Published
Organisations: Applied functional analysis, Department of Mathematics, University of Colorado, University of Colorado at Colorado Springs
Authors: Kreissl, S. (Ekstern), Pingen, G. (Ekstern), Evgrafov, A. (Intern), Maute, K. (Ekstern)
Pages: 1478
Publication date: 2009

**Host publication information**
Title of host publication: WCSMO-8 : Eighth World Congress on Structural and Multidisciplinary Optimization
Main Research Area: Technical/natural sciences
Conference: 8th World Congress on Structural and Multidisciplinary Optimization, Lisbon, Portugal, 01/06/2009 - 01/06/2009
Links:
http://www.wcsmo8.org

Source: orbit
Source-ID: 228797
Publication: Research - peer-review › Journal article – Annual report year: 2009

Design of Piezoelectric Energy Harvesting Systems: A Topology Optimization Approach Based on Multilayer Plates and Shells

**General information**
State: Published
Organisations: Applied functional analysis, Department of Mathematics, University of Colorado
Isogeometric Analysis in Structural Analysis

General information
State: Published
Organisations: Department of Mathematics, Applied functional analysis, Solid Mechanics, Department of Mechanical Engineering, Geometry
Authors: Nguyen, D. M. (Intern), Evgrafov, A. (Intern), Gersborg, A. R. (Intern), Gravesen, J. (Intern)
Event: Poster session presented at DCAMM 12th Internal Symposium, Ringsted, Denmark.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 257742
Publication: Research - peer-review › Poster – Annual report year: 2009

Isogeometric Design of Vibrating Membranes

General information
State: Published
Organisations: Department of Mathematics, Applied functional analysis, Solid Mechanics, Department of Mechanical Engineering, Geometry
Authors: Nguyen, D. M. (Intern), Evgrafov, A. (Intern), Gersborg, A. R. (Intern), Gravesen, J. (Intern)
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 257743
Publication: Research - peer-review › Poster – Annual report year: 2009

Optimal synthesis of tunable elastic wave-guides

General information
State: Published
Organisations: Applied functional analysis, Department of Mathematics, University of Colorado at Boulder, University of Colorado
Authors: Evgrafov, A. (Intern), Rupp, C. J. (Ekstern), Dunn, M. L. (Ekstern), Maute, K. (Ekstern)
Pages: 1610-1610
Publication date: 2009

Host publication information
Title of host publication: WCSMO-8 : Eighth World Congress on Structural and Multidisciplinary Optimization
Main Research Area: Technical/natural sciences
Conference: 8th World Congress on Structural and Multidisciplinary Optimization, Lisbon, Portugal, 01/06/2009 - 01/06/2009
Source: orbit
Source-ID: 244322
Publication: Research - peer-review › Article in proceedings – Annual report year: 2009

Parametrisation in Iso geometric Analysis: A first report

General information
State: Published
Organisations: Department of Mathematics, Department of Mechanical Engineering
Authors: Nguyen, D. M. (Intern), Nielsen, P. N. (Intern), Gersborg, A. R. (Intern), Evgrafov, A. (Intern), Gravesen, J. (Intern)
Number of pages: 10
Publication date: 2009

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions: first-report.pdf
Topology optimization for nano-scale heat transfer

We consider the problem of optimal design of nano-scale heat conducting systems using topology optimization techniques. At such small scales the empirical Fourier's law of heat conduction no longer captures the underlying physical phenomena because the mean-free path of the heat carriers, phonons in our case, becomes comparable with, or even larger than, the feature sizes of considered material distributions. A more accurate model at nano-scales is given by kinetic theory, which provides a compromise between the inaccurate Fourier's law and precise, but too computationally expensive, atomistic simulations. We analyze the resulting optimal control problem in a continuous setting, briefly describing the computational approach to the problem based on discontinuous Galerkin methods, algebraic multigrid preconditioned generalized minimal residual method, and a gradient-based mathematical programming algorithm. Numerical experiments with our implementation of the proposed numerical scheme are reported.

General information
State: Published
Organisations: Applied functional analysis, Department of Mathematics, University of Colorado at Boulder
Authors: Evgrafov, A. (Intern), Maute, K. (Ekstern), Yang, R. (Ekstern), Dunn, M. L. (Ekstern)
Pages: 285-300
Publication date: 2009
Main Research Area: Technical/natural sciences

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BFI (2017): BFI-level 2
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Scopus rating (2016): CiteScore 2.64 SJR 1.743 SNIP 1.566
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.912 SNIP 1.689 CiteScore 2.67
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.935 SNIP 1.927 CiteScore 2.73
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.415 SNIP 1.894 CiteScore 2.8
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.47 SNIP 2.103 CiteScore 2.7
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.193 SNIP 1.935 CiteScore 2.47
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.177 SNIP 1.717
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.983 SNIP 1.601
Web of Science (2009): Indexed yes
**Topological optimization of piezoelectric energy harvesting structures and circuits**

**General information**
State: Published
Organisations: Applied functional analysis, Department of Mathematics, University of Colorado at Boulder, University of Colorado
Authors: Rupp, C. J. (Ekstern), Evgrafov, A. (Intern), Dunn, M. L. (Ekstern), Maute, K. (Ekstern)
Pages: 1594
Publication date: 2009

**Host publication information**
Title of host publication: WCSMO-8 : Eighth World Congress on Structural and Multidisciplinary Optimization
Main Research Area: Technical/natural sciences
Conference: 8th World Congress on Structural and Multidisciplinary Optimization, Lisbon, Portugal, 01/06/2009 - 01/06/2009
Links:
http://www.wcsmo8.org
Source: orbit
Source-ID: 244321
Publication: Research - peer-review › Article in proceedings – Annual report year: 2009

**Optimal synthesis of tunable elastic wave-guides**
Topological optimization, or control in the coefficients of partial differential equations, has been successfully utilized for designing wave-guides with precisely tailored functionalities. For many applications it would be desirable to have the possibility of drastically altering the wave-guiding properties of a device “on the fly,” in a controllable manner as an influence of some external input. This would enable wave-guides with highly non-linear input–output mappings, such as for example controllable wave switches. In this paper, we propose using finite elastic pre-straining for the purpose of tuning a wave-guide. In order to systematically formulate and solve the wave-guide synthesis problems we utilize mathematical programming methods in conjunction with topology optimization for parametrizing the design space. The resulting extremal problem is, from a practical point, equivalent to finding an optimal subdivision of a given control volume into two disjoint subsets occupied by two different materials, normally resulting in a highly heterogeneous elastic body with desired wave-guiding functionalities in the original and finitely deformed configurations. The proposed methodology is illustrated with numerical examples.
Projects:

**Efficient 3D Shape Optimization**

Department of Applied Mathematics and Computer Science  
**Period:** 01/09/2017 → 31/08/2020  
**Number of participants:** 3  
**Phd Student:** Limkilde, Asger (Intern)  
**Supervisor:** Evgrafov, Anton (Intern)  
**Main Supervisor:** Gravesen, Jens (Intern)

**Financing sources**

Source: Internal funding (public)  
Name of research programme: Institut stipendie (DTU)  
Project: PhD

**Mathematical Analysis and Computations for Multiphysics Tomography**

Department of Applied Mathematics and Computer Science  
**Period:** 15/12/2015 → 13/06/2019  
**Number of participants:** 4  
**Phd Student:** Kirkeby, Adrian (Intern)  
**Supervisor:** Evgrafov, Anton (Intern)  
**Karamedovic, Mirza (Intern)**  
**Main Supervisor:** Knudsen, Kim (Intern)

**Financing sources**

Source: Internal funding (public)  
Name of research programme: Institut stipendie (DTU)  
Project: PhD

**Topology Optimization and Lattice Bolzmann Methods**

Department of Mechanical Engineering  
**Period:** 01/09/2014 → 31/10/2017  
**Number of participants:** 7  
**Phd Student:** Nørgaard, Sebastian Arlund (Intern)  
**Supervisor:** Engelbrecht, Kurt (Intern)  
**Lazarov, Boyan Stefanov (Intern)**  
**Main Supervisor:** Sigmund, Ole (Intern)
Examiner:
Fuhrman, David R. (Intern)
Evgrafov, Anton (Intern)
Stingl, Michael Walter (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

Optimization on Manifolds - with applications to shape optimization.
Department of Applied Mathematics and Computer Science
Number of participants: 7
Phd Student:
Møller-Andersen, Jakob (Intern)
Supervisor:
Evgrafov, Anton (Intern)
Nørtoft, Peter (Intern)
Main Supervisor:
Gravesen, Jens (Intern)
Examiner:
Markvorsen, Steen (Intern)
Grandine, Thomas A. (Ekstern)
Michor, Peter W. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)

Relations
Publications:
Optimization on Spaces of Curves
Project: PhD

Mathematical programming methods for large-scale structural topology optimization
Department of Wind Energy
Period: 01/09/2012 → 28/01/2016
Number of participants: 6
Phd Student:
Rojas Labanda, Susana (Intern)
Supervisor:
Sigmund, Ole (Intern)
Main Supervisor:
Stolpe, Mathias (Intern)
Examiner:
Jensen, Jakob Søndergaard (Intern)
Evgrafov, Anton (Intern)
Stingl, Michael Walter (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Eksternt finansieret virksomhed

Relations
Activities:
DCAMM 15th Internal Symposium
DCAMM 14th Internal Symposium
Mathematical Modelling and Optimization of Nano Mechanical Devices

Department of Applied Mathematics and Computer Science
Period: 15/12/2011 → 28/04/2015
Number of participants: 6
Phd Student:
Adesokan, Bolaji James (Intern)
Supervisor:
Sørensen, Mads Peter (Intern)
Main Supervisor:
Evgrafov, Anton (Intern)
Examiner:
Hjorth, Poul G. (Intern)
Berg, Peter (Ekstern)
Fuhrmann, Jürgen (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Eksternt finansieret virksomhed
Project: PhD

Adaptive Simulations of Nonlinear Structures in Magnetized Plasma

Department of Physics
Period: 15/09/2010 → 24/10/2014
Number of participants: 4
Phd Student:
Treue, Frederik (Intern)
Supervisor:
Engsig-Karup, Allan Peter (Intern)
Evgrafov, Anton (Intern)
Main Supervisor:
Naulin, Volker (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD

Large-Scale Algorithms for Non-Smooth Convex Optimization

Department of Applied Mathematics and Computer Science
Period: 01/02/2010 → 22/11/2013
Number of participants: 6
Phd Student:
Skajaa, Anders (Intern)
Supervisor:
Jørgensen, John Bagterp (Intern)
Main Supervisor:
Hansen, Per Christian (Intern)
Examiner:
Evgrafov, Anton (Intern)
Gondzio, Jacek (Ekstern)
Vandenberghe, Lieven (Intern)

Financing sources
Dimension reduction methods applied to mechanical systems

Department of Informatics and Mathematical Modeling
Period: 15/12/2009 → 20/03/2014
Number of participants: 7
PhD Student:
Elmegård, Michael (Intern)
Supervisor:
Evgrafov, Anton (Intern)
Thomsen, Jon Juel (Intern)
Main Supervisor:
Starke, Jens (Intern)
Examiner:
Hjorth, Poul G. (Intern)
Kerschen, Gaëtan (Ekstern)
Sieber, Jan (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Iso-geometric analysis and shape optimization in electromagnetism

Department of Mathematics
Period: 15/02/2009 → 29/05/2012
Number of participants: 6
PhD Student:
Nguyen, Dang Manh (Intern)
Supervisor:
Evgrafov, Anton (Intern)
Main Supervisor:
Gravesen, Jens (Intern)
Examiner:
Breinbjerg, Olav (Intern)
Dokken, Tor (Ekstern)
Grandine, Thomas A. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Fluid Optimisation Workflows for Highly Effective Automotive Development Processes

The automotive industry has recently seen a paradigmatic shift from design processes based on physical prototypes to a computationally aided product development process (PDP) based on virtual prototypes. To maintain the competitiveness of European car manufacturers, a significant reduction of lead development time is required. The main potential for improvement lies in further exploitation of virtual development and especially in further automation of these virtual processes through optimal design techniques. Optimal design techniques are mature and are being used in structural mechanics in the automotive industry, as well as in computational fluid dynamics (CFD) in the aeronautical industry. However, this potential has not yet been realised for CFD in the automotive industry. To integrate these methods into workflows within the routine PDP, the project will make advances with adjoint sensitivity methods, mesh-based and CAD-based shape optimisation, high-Reynolds number topology optimisation. Complete CFD optimisation workflows, i.e. chains of optimisation techniques adapted to the automotive processes for the early as well as later stages of development will be integrated into the PDP. Aspects of process stability, data management, storage, numerical efficiency will be addressed in conjunction with an analysis of current PDP practices. The current practices of organising the PDP will be analysed, the areas of potential for optimisation workflows identified and where necessary alterations of the PDP will be made. Key use cases within the design process defined by the two car manufacturers in the project will be demonstrated and the resulting
reduction in lead time will be validated. European SMEs play a leading role in developing the software tools for the PDP and in supporting the car manufacturers in implementing these tools in their PDPs. Three SMEs with a track record of working with the automotive industry are partners in the project.

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CD-adapco
ESI Group S.A.
FE-Design GmbH
ICON Computer Graphics Ltd.
Renault S.A.S.
Technische Universität München
Technical University of Sofia
Volkswagen AG

Waraw University of Technology
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Financing sources
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Name of research programme: Forsk. EU - Rammeprogram
Amount: 2,500,000.00 Danish Kroner

Topology Optimization for Crashworthiness Design Using Approximate Procedures

Department of Mathematics
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Topology Optimization Problems with Design-Dependent Sets of Constraints

Department of Mathematics
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Project: PhD