Workshop em Otimização e Problemas Inversos

Universidade Federal de Santa Catarina

October, 24^{th} to $27^{t}h$, 2023

Scientific committee

Maicon Marques Alves (UFSC)
Maria Soledad Aronna (FGV EMAp)
Antonio Leitão (UFSC)
Majela Penton Machado (UFBA)
Yuri Saporito (FGV EMAp)

Organizing committee

Maicon Marques Alves (UFSC)
Vinícius Albani (UFSC)
Rafaela Filippozzi (UFSC)
Marina Geremia (IFSC)
Douglas S. Gonçalves (UFSC)
Marianna Ravara Vago (UFSC)

Sponsors and local support

INCTMat CAPES UFSC

Workshop schedule

	Tuesday Oct 24	Wednesday Oct 25	Thursday Oct 26	Friday Oct 27
8:30 – 9:00	ARRIVAL/Opening			
9:00 – 9:30	F. Margotti	A. Mercado	D. Santos	V. Guigues*
9:30 – 10:00	L. -R. Santos	C. Costa	J. G. Melo	M. S. Aronna*
10:00 – 10:30	Coffee Break	Coffee Break	Coffee Break	Coffee Break
10:30 – 11:00	J. B. Francisco	R. T. Marcavillaca	R. Behling	E. Boos
11:00 – 11:45	A. IUSEM	E. MIQUELES	L. BARICHELLO	U. ASCHER*
11:45 – 13:45	Lunch Break	Lunch	Lunch Break	Lunch
13:45 – 14:30	B. SVAITER	Free Afternoon 20:00 - Workshop dinner	P. THOMPSON	
14:30 – 15:00	G. Haeser		J. M. Pereira	
15:00 – 15:30	M. Gonçalves		W. Muniz	
15:30 – 16:00	Coffee Break		Coffee Break	
16:00 – 16:45	D. LORENZ		B. KALTENBACHER*	
16:45 – 17:15	M. Sicre		D. S. Gonçalves	

(*) Remote Talk

Plenary speakers

Alfredo Iusem (IMPA, EMAp-FGV)

Title: A finitely convergent circumcenter method for the convex feasibility problem

Abstract: In this paper, we present a variant of the circumcenter method for the Convex Feasibility Problem (CFP), for which finite convergence is ensured under a Slater assumption. The method replaces exact projections onto the convex sets by projections onto separating halfspaces, per- turbed by an exogenous perturbation parameter which decreases to zero along the iterations. If the perturbation parameters go to zero slowly enough (say, the series of the perturbation parameters diverges), then convergence is finite. This is to our knowledge, the first finitely convergent circumcenter method for CFP.

Joint work with R. Behling, J.Y. Bello Cruz, Di Liu and L.-R. Santos.

Barbara Kaltenbacher* (Alpen-Adria-Universität Klagenfurt)

Title: Optimization based formulation and solution of inverse problems

Abstract: The probably most well-known and most widely used approach to solving inverse problems is by combined minimization of data misfit and some regularization term, usually referred to as Tikhonov-Philips regularization. Still, this relies on the use of some forward operator, which is the concatenation of the observation operator with the parameter-to-state-map for the underlying model. Recently, all-at-once formulations have been considered as an alternative to this reduced formulation, avoiding the use of a parameter-to-state map, which would sometimes lead to too restrictive conditions. Here the model and the observation are considered simultaneously as one large system with the state and the parameter as unknowns. A still more general formulation of inverse problems, containing both the reduced and the all-at-once formulation, but also the well-known and highly versatile so-called variational approach (not to be mistaken with variational regularization) as special cases, is to formulate the inverse problem as a minimization problem (instead of an equation) for the state and parameter. Regularization can be incorporated via imposing constraints and/or adding regularization terms to the objective. In this talk, after providing the general setting with convergence results, we will discuss some examples and in particular dwell on some applications in (nonlinear) acoustics.

Benar F. Svaiter (IMPA)

Title: TBA

Abstract: TBA

Dirk A. Lorenz (TU Braunschweig)

Title: The degenerate precondtioned proximal point method

Abstract: We take a new look at the proximal point method for maximal monotone inclusions in Hilbert spaces and especially on the preconditioned case. We observe that if we allow the preconditioner to be degenerate, i.e. having a non-trivial kernel, but otherwise being positive semi-definite, we obtain several know splitting methods, especially the Douglas-Rachford method, in a natural way as preconditioned proximal point method. Motivated by this we derive convergence theory in the degenerate case and show that many convergence results still hold in this case. We also observe that the phenomenon, that the Douglas-Rachford method only iterates in just one variable, can be generalized: The dimension of the kernel of the preconditioner indicates, how many variables are actually needed for the iteration.

The framework of degenerate preconditioners helps to discover many more splitting methods, e.g. also a sequential generalization of the Douglas-Rachford method. If time permits, we also discuss the generalization of the hybrid proximal extragradient method to the degenerate case.

Liliane Barichello (UFRGS)

Title: On Inverse Problems in Particle Transport Theory

Abstract: Describing the distribution and transport of neutral particles in a material media is the subject of interest in phenomena such as light propagation in optical tomography (OT) simulations, neutron transport in nuclear non-proliferation applications (NP), and radiation dose calculations in radiotherapy planning (RP). Solving several inverse problems is a crucial step for dealing with such issues. For instance, estimating absorption and scattering parameters to characterize the biological tissue in (OT); reconstructing particle sources in (NP); and estimating boundary conditions in (RP).

A basic mathematical model to deal with these problems is the linear version of the Boltzmann equation. The solution of this equation, in other words, the direct problem, is an important aspect when solving the inverse problems mentioned above.

This talk presents an overview of solutions developed over the years to deal with neutral particle inverse problems. Tikhonov regularization, as well as

Bayesian inference approaches, are analyzed. Particular attention is given to the use of explicit solutions for the direct problem in solving the inverse scheme. Ongoing projects in this field raising new demands on inverse approaches will also be discussed.

Maria Soledad Aronna* (EMAp-FGV)

Title: Optimal control in biological and epidemiological models

Abstract: In this talk we describe some models of optimal control in biological/epidemiological models, such as biological control of insects, vaccine allocation and testing strategies. We show situations that Optimal Control Theory could successfully solve and we present and discuss some challenges for the future of the field.

Philip Thompson (EMAp-FGV)

Title: TBA

Abstract: TBA.

Uri Ascher* (UBC)

Title: Optimization methods for problems involving differential equations with constraints arising in visual computing and robotics

Abstract: We examine optimization issues in computational methods for solving non-linear constrained PDEs in large applications.

One project involves simulation of friction and contact effects in deformable object motion arising in computer graphics and robotics. The need to flexibly engage such constraints in differentiable models prompts introduction of penalty methods and fractional-step methods, despite some additional complexity and minor potential instabilities.

Another project investigates, in the context of neural differential equations, different stabilization methods for differential equations on invariant manifolds arising from elimination of algebraic constraints.

Invited speakers

Alberto Mercado Saucedo (UTFSM)

Title: Inverse problems for transmission wave equations

Abstract: In this talk we present results on the stability of the inverse problem consisting in recovering a coefficient in hyperbolic equations with discontinuous main coefficient, which can be seen as a transmission system.

The main tool is given by Carleman estimates, and the Bukgheim-Klibanov strategy, which gives Lipschitz stability around a given trajectory. The main difficulty is the construction of the weight function. We pay special attention to the interface geometry and to the estimation of the time needed to have stability.

We will present some results on convex and non-convex interfaces, and also a recent result on flat interfaces with an accurate estimate of the minimum time.

Carina M. Costa (IFPR)

Title: Mixed-Integer Programming Techniques for the Minimum Sum-of-Squares Clustering Problem

Abstract: The minimum sum-of-squares clustering problem is a very important problem in data mining and machine learning with very many applications in, e.g., medicine or social sciences. However, it is known to be NP-hard in all relevant cases and to be notoriously hard to be solved to global optimality in practice. In this work, we develop and test different tailored mixed-integer programming techniques to improve the performance of state-of-the-art MINLP solvers when applied to the problem—among them are cutting planes, propagation techniques, branching rules, or primal heuristics. Our extensive numerical study shows that our techniques significantly improve the performance of the open-source MINLP solver SCIP. Consequently, using our novel techniques, we can solve many instances that are not solvable with SCIP without our techniques and we obtain much smaller gaps for those instances that can still not be solved to global optimality.

Joint work with: Jan Pablo Burgard, Cristopher Hojny, Thomas Kleinert, and Martin Schmidt.

Daiana Oliveira dos Santos (UNIFESP)

Title: Strong global convergence properties of an Augmented Lagrangian method for symmetric cones

Abstract: Sequential optimality conditions have played a major role in proving stronger global convergence results for numerical algorithms used in nonlinear programming. Several extensions have been described in conic contexts, leading to many open questions. In this talk, we will present new sequential optimality conditions for nonlinear symmetric cone programming. Stronger results are obtained by exploiting the rich algebraic structure of the problem.

Douglas S. Gonçalves (UFSC)

Title: On the convergence of Levenberg-Marquardt with Singular Scaling matrices

Abstract: Based on certain regularization techniques for linear inverse problems, we investigate convergence properties of the Levenberg-Marquardt method (LM) using a singular scaling matrix to replace the usual identity matrix. This allows us to employ a broader class of regularizers and still preserve nice local and global convergence properties under completeness and error bound conditions. For instance, in the case of zero residue problems it is possible to show local quadratic convergence. Moreover, by using a line search scheme global convergence to stationary points of the sum of squares function can be established for LM with singular scaling.

Eduardo Miqueles (LNLS)

Title: Two-dimensional phase retrieval in the Fraunhofer regime using Fisher information through iterations

Abstract: We discuss numerical inverse problems arising in some of the imaging beamlines from Sirius, and their respective numerical implementations. One of the most challenging problems in this area concerns phase-retrieval for coherent diffraction images. Some new and alternative mathematical ideas regarding phase inversion will be presented, using new approaches to the measured image in the reciprocal space and in the real space. These ideas can help us to find local minima of feasibility problems that are solved through a sequence of proximal points.

Everton Boos (UFSC)

Title: Thermal conductivity reconstruction with Chebyshev pseudospectral method and applications

Abstract: We present a numerical method to reconstruct the spatially varying thermal conductivity coefficient of a 2D transient heat conduction model using

input data collected from internal temperature measurements. The reconstruction problem is formulated as a non-linear minimization problem, which we solve by a Levenberg-Marquardt method (LMM) along with singular scaling matrices to enforce smoothness on the iterates and the discrepancy principle to avoid the iterates being dominated by noise. In this method, the conduction model is repeatedly solved by combining a pseudospectral method in the spatial domain and an implicit trapezoidal rule in the time interval. The accuracy and efficiency of the proposed method is assessed by numerical examples using synthetic noisy data. Estimation results are also presented with experimental data taken from the literature for a machining process of face milling on AISI 4340 steel.

Fábio Margotti (UFSC)

Title: Inexact Newton regularizations with uniformly convex stability terms: A unified convergence analysis

Abstract: We present a unified convergence analysis of inexact Newton regularizations for nonlinear ill-posed problems in Banach spaces. These schemes consist of an outer (Newton) iteration and an inner iteration which provides the update of the current outer iterate. To this end the nonlinear problem is linearized about the current iterate and the resulting linear system is approximately (inexactly) solved by an inner regularization method. In our analysis we only rely on generic assumptions of the inner methods and we show that a variety of regularization techniques satisfies these assumptions. For instance, gradient-type and iterated-Tikhonov methods are covered. Not only the technique of proof is novel, but also the results obtained, because for the first time uniformly convex penalty terms stabilize the inner scheme.

Gabriel Haeser (USP)

Title: Constant rank constraint qualification for nonlinear second-order cone programming

Abstract: We revisit the classical notions of nondegeneracy and Robinson's condition in the context of nonlinear second-order cone programming. For an m-dimensional second-order cone, instead of stating nondegeneracy at the vertex as the linear independence of m derivative vectors, we do it in terms of several statements of linear independence of two derivative vectors. This allows embedding the structure of the second-order cone into the formulation of the conditions, providing weaker variants and applications.

João M. Pereira (IMPA)

Title: The implicit method of moments

Abstract: The method of moments is a classical inverse problem in statistics. It consists of extracting information of datasets by analysing and decomposing its empirical moments, which are averages over the whole dataset of several quantities of interest. The idea has its base on the law of large numbers: while individual samples are noisy, by averaging over the whole dataset the noise (nearly) goes away and we obtain something more similar to a classical inverse problem. Our focus is on the multivariate method of moments, where most of the applications focus on using only the first two moments, the mean and covariance. That is with some reason, as higher order moments are huge multi-dimensional arrays that can be hard to store and use to do computations. I will introduce the idea of implicit method of moments, which consists of using samples directly to calculate quantities that involve the moment tensors, that way avoiding forming these very big multi-dimensional arrays. We show how we can use the implicit method of moments and non-convex optimization to obtain an algorithm for estimating Gaussian Mixture Models that is competitive with the state-of-the-art.

Jefferson G. Melo (UFG)

Title: Iteration-Complexity of an Inexact Proximal Augmented Lagrangian Method for Solving Constrained Composite Optimization Problems

Abstract: In this talk, we will analyze the iteration-complexity of an inexact proximal augmented Lagrangian method for solving constrained (nonconvex) composite optimization problems. Each iteration of the proposed method consists of inexactly solving a proximal augmented Lagrangian subproblem by an accelerated composite gradient (ACG) algorithm followed by a Lagrange multiplier update. It is shown that the proposed method generates a p-approximate stationary solution in at most $O(1/p^3)$ ACG iterations, where $p > 0$ is a given tolerance. It is also shown that the previous complexity bound can be sharpened to $O(1/p^{2.5})$ if the Lagrangian multipliers are updated in a special way. The above bounds are derived without assuming that the initial point is feasible. Some preliminary numerical results are presented to illustrate the performance of the proposed method.

Joint work with Renato D.C. Monteiro-Georgia Tech and Weiwei Kong-Google Research(NYC).

Juliano de Bem Francisco (UFSC)

Title: Quasi-Newton interior point method for nonlinear system of equations under box constraints

Abstract: System of nonlinear equations under some kind of constraints is a major problem that appears in numerical analysis which often raises interesting challenges. Its applications can be seen in engineering, economic sciences, biology and other applied sciences. In this talk we deal with nonlinear systems of equations with box constraints, that is, the solution must respect some bounds (lower and upper bounds). We propose an algorithm based on an affine scaling matrix (well-known in the literature) combined with quasi-Newton-secant update schemes, which leads to a Jacobian-free approach for this particular mathematical problem. Under some usual assumptions we assure that the algorithm either converges to a solution or to a stationary point of an auxiliary minimization problem. Numerical results show that the computational performance of our method outperforms by far the standard algorithm based on the discrete Newton approach.

Luiz-Rafael Santos (UFSC)

Title: Randomized Preconditioners for linear systems arising from Interior Point Methods

Abstract: In this study, we focus on the efficient solution of data-driven, frequently dense, convex LPs and QPs, especially as they pertain to L1/L2 SVMs, portfolio optimization, and regression techniques like Elastic Net. Using the robust capabilities of Interior Point Methods (IPMs) and complementing them with sketching and random numerical linear algebra (randNLA) strategies, we formulate specialized randomized preconditioners tailor-made for these challenges. Furthermore, we present an IPM explicitly designed to manage box constraints, emphasizing its effectiveness through real-world data demonstrations. Our research offers insights and guidance on selecting the most appropriate preconditioners for diverse situations.

Maurício R. Sicre (UFBA)

Title: A Projective Splitting Method for Monotone Inclusions: Iteration-Complexity and Application to Composite Optimization

Abstract: This is a joint work with Majela Penton (UFBA). We propose an inexact projective splitting method to solve the problem of finding a zero of a sum of maximal monotone operators. We perform convergence and complexity analyses of the method by viewing it as a special instance of an inexact proximal point method proposed by Solodov and Svaiter in 2001, for which pointwise and ergodic complexity results have been studied recently by Sicre. Also, for this latter method, we establish convergence rates and complexity bounds for strongly monotone inclusions, from where we obtain linear convergence for our projective

splitting method under strong monotonicity and cocoercivity assumptions. We apply the proposed projective splitting scheme to composite convex optimization problems and establish pointwise and ergodic function value convergence rates.

Max Leandro Gonçalves (UFG)

Title: Subsampled cubic regularization method for finite-sum minimization

Abstract: In this talk, we discuss and analyze a subsampled Cubic Regularization Method (CRM) for solving finite-sum optimization problems. The new method uses random subsampling techniques to approximate the functions, gradients and Hessians in order to reduce the overall computational cost of the CRM. Under suitable hypotheses, first- and second-order iteration-complexity bounds and global convergence analyses are presented. We also discuss the local convergence properties of the method. Numerical experiments are presented to illustrate the performance of the proposed scheme.

Raul T. Marcavillaca (UFSC)

Title: Proximal point type algorithms for nonconvex pseudomonotone equilibrium problems

Abstract: In this talk, we present an overview of recent works regarding proximal point-type algorithms for nonconvex pseudomonotone equilibrium problems. We discuss the usual proximal method, the relaxed-inertial method, the two-step extragradient method and the extragradient projected method, all of them for pseudomonotone equilibrium problems which are neither convex nor differentiable on the second argument of the bifunction. Finally, we present applications for classes of mixed variational inequalities based on fractional programming problems.

Roger Behling (UFSC)

Title: On the Centralization of the Circumcentered-Reflection Method

Abstract: In this talk, we present the first circumcenter iteration scheme that does not employ a product space reformulation for finding a point in the intersection of two closed convex sets. We introduce a so-called centralized version of the circumcentered-reflection method (CRM). Developed with the aim of accelerating classical projection algorithms, CRM is successful for tracking a common point of a finite number of affine sets. In the case of general convex sets, CRM was shown to possibly diverge if Pierra's product space reformulation is not used. In this work, we prove that there exists an easily reachable region consisting of what we refer to as centralized points, where pure circumcenter steps possess properties yielding convergence. The resulting algorithm is called centralized CRM (cCRM). In addition to having global convergence, cCRM converges linearly under an error bound condition, and superlinearly if the two target sets are so that their intersection have nonempty interior and their boundaries are locally differentiable manifolds. We also present numerical experiments with successful results.

Vincent Guigues (FGV)

Title: Constant Depth Decision Rules for multistage optimization under uncertainty

Abstract: In this paper, we introduce a new class of decision rules, referred to as Constant Depth Decision Rules (CDDRs), for multistage optimization under linear constraints with uncertainty-affected right-hand sides. We consider two uncertainty classes: discrete uncertainties which can take at each stage at most a fixed number d of different values, and polytopic uncertainties which, at each stage, are elements of a convex hull of at most d points. Given the depth mu of the decision rule, the decision at stage t is expressed as the sum of t functions of mu consecutive values of the underlying uncertain parameters. These functions are arbitrary in the case of discrete uncertainties and are poly-affine in the case of polytopic uncertainties. For these uncertainty classes, we show that when the uncertain right-hand sides of the constraints of the multistage problem are of the same additive structure as the decision rules, these constraints can be reformulated as a system of linear inequality constraints where the numbers of variables and constraints is $O(1)(n+m)d^m uN^2$ with n the maximal dimension of control variables, m the maximal number of inequality constraints at each stage, and N the number of stages. As an illustration, we discuss an application of the proposed approach to a Multistage Stochastic Program arising in the problem of hydro-thermal production planning with interstage dependent inflows. For problems with a small number of stages, we present the results of a numerical study in which optimal CDDRs show similar performance, in terms of optimization objective, to that of Stochastic Dual Dynamic Programming (SDDP) policies, often at much smaller computational cost.

Wagner Muniz (UFSC)

Title: TBA

Abstract: TBA.