Image reconstruction under non-Gaussian noise

During acquisition and transmission, images are often blurred and corrupted by noise. One of the fundamental tasks of image processing is to reconstruct the clean image from a degraded version. The process of recovering the original image from the data is an example of an inverse problem. Due to the ill-posedness of the problem, the simple inversion of the degradation model does not give any good reconstructions. Therefore, to deal with the ill-posedness it is necessary to use some prior information on the solution or the model and the Bayesian approach.

Additive Gaussian noise has been extensively studied since it produces simple and tractable mathematical models. However, in the real applications, the noise is much more complicated and it cannot be well simulated by additive Gaussian noise, for instance, it may be signal dependent, very impulsive, multiplicative, mixed, etc. This PhD thesis intends to solve some of the many open questions for image restoration under non-Gaussian noise. The two main kinds of noise studied in this PhD project are the impulse noise and the Cauchy noise.

Impulse noise is due to for instance the malfunctioning pixel elements in the camera sensors, errors in analogue-to-digital conversion, faulty memory locations in hardware. Cauchy noise is characterized by a very impulsive behaviour and it is mainly used to simulate atmospheric and underwater acoustic noise, in radar and sonar applications, biomedical images and synthetic aperture radar images. For both noise models we introduce new variational models to recover the clean and sharp images from degraded images. Both methods are verified by using some simulated test problems. The experiments clearly show that the new methods outperform the former ones.

Furthermore, we have carried out a theoretical study on the two most known estimates: maximum a posteriori (MAP) estimate and conditional mean (CM) estimate for non-Gaussian noise. With only the convexity assumption on the data fidelity term, we introduce some cost functions for which the CM and MAP estimates are proper Bayes estimators and we also prove that the CM estimate outperforms the MAP estimate, when the error depends on Bregman distances.

This PhD project can have many applications in the modern society, in fact the reconstruction of high quality images with less noise and more details enhances the image processing operations, such as edge detection, segmentation, etc.
Lackos Bidiagonalization with Subspace Augmentation for Discrete Inverse Problems

The regularizing properties of Lanczos bidiagonalization are powerful when the underlying Krylov subspace captures the dominating components of the solution. In some applications the regularized solution can be further improved by augmenting the Krylov subspace with a low-dimensional subspace that represents specific prior information. Inspired by earlier work on GMRES we demonstrate how to carry these ideas over to the Lanczos bidiagonalization algorithm.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Gifu Shotoku Gakuen University
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Tomographic image reconstruction using training images

We describe and examine an algorithm for tomographic image reconstruction where prior knowledge about the solution is available in the form of training images. We first construct a non-negative dictionary based on prototype elements from the training images; this problem is formulated within the framework of sparse learning as a regularized non-negative matrix factorization. Incorporating the dictionary as a prior in a convex reconstruction problem, we then find an approximate solution with a sparse representation in the dictionary. The dictionary is applied to non-overlapping patches of the image, which reduces the computational complexity compared to previous formulations. Computational experiments clarify the choice and interplay of the model parameters and the regularization parameters, and we show that in few-projection low-dose settings our algorithm is competitive with total variation regularization and tends to include more texture and more correct edges.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Fingerprint Cards AB
Authors: Soltani, S. (Ekstern), Andersen, M. S. (Intern), Hansen, P. C. (Intern)
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User-friendly simultaneous tomographic reconstruction and segmentation with class priors

Simultaneous Reconstruction and Segmentation (SRS) strategies for computed tomography (CT) present a way to combine the two tasks, which in many applications traditionally are performed as two successive and separate steps. A combined model has a potentially positive effect by allowing the two tasks to influence one another, at the expense of a more complicated algorithm. The combined model increases in complexity due to additional parameters and settings requiring tuning, thus complicating the practical usability. This paper takes it outset in a recently published variational algorithm for SRS. We propose a simplification that reduces the number of required parameters, and we perform numerical experiments investigating the effect and the conditions under which this approach is feasible.
A Spectral Geometrical Model for Compton Scatter Tomography Based on the SSS Approximation
The forward model of single scatter in the Positron Emission Tomography for a detector system possessing an excellent spectral resolution under idealized geometrical assumptions is investigated. This model has the form of integral equations describing a flux of photons emanating from the same annihilation event and undergoing a single scattering at a certain angle. The equations for single scatter calculation are derived using the Single Scatter Simulation approximation. We show that the three-dimensional slice-by-slice filtered backprojection algorithm is applicable for scatter data inversion provided some assumptions on the attenuation map are justified.

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Organisations: Department of Physics, Neutrons and X-rays for Materials Physics, Department of Applied Mathematics and Computer Science, Scientific Computing, Institute of Computational Mathematics and Mathematical Geophysics
Authors: Kazantsev, I. G. (Ekstern), Olsen, U. L. (Intern), Poulsen, H. F. (Intern), Hansen, P. C. (Intern)
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A tensor-based dictionary learning approach to tomographic image reconstruction
We consider tomographic reconstruction using priors in the form of a dictionary learned from training images. The reconstruction has two stages: first we construct a tensor dictionary prior from our training data, and then we pose the reconstruction problem in terms of recovering the expansion coefficients in that dictionary. Our approach differs from past approaches in that (a) we use a third-order tensor representation for our images and (b) we recast the reconstruction problem using the tensor formulation. The dictionary learning problem is presented as a non-negative tensor factorization problem with sparsity constraints. The reconstruction problem is formulated in a convex optimization framework by looking for a solution with a sparse representation in the tensor dictionary. Numerical results show that our tensor formulation leads to very sparse representations of both the training images and the reconstructions due to the ability of representing repeated features compactly in the dictionary.

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Convergence analysis for column-action methods in image reconstruction

Column-oriented versions of algebraic iterative methods are interesting alternatives to their row-version counterparts: they converge to a least squares solution, and they provide a basis for saving computational work by skipping small updates. In this paper we consider the case of noise-free data. We present a convergence analysis of the column algorithms, we discuss two techniques (loping and flagging) for reducing the work, and we establish some convergence results for methods that utilize these techniques. The performance of the algorithms is illustrated with numerical examples from computed tomography.

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Scopus rating (2012): SJR 0.994 SNIP 1.398 CiteScore 1.38
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Scopus rating (2011): SJR 0.765 SNIP 1.213 CiteScore 1.18
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Scopus rating (2009): SJR 0.554 SNIP 0.794
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Scopus rating (2008): SJR 0.741 SNIP 1.072
Scopus rating (2007): SJR 0.597 SNIP 1.11
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.531 SNIP 0.861
Scopus rating (2005): SJR 0.657 SNIP 0.813
Web of Science (2005): Indexed yes
High-definition velocity-space tomography of fast-ion dynamics

Velocity-space tomography of the fast-ion distribution function in a fusion plasma is usually a photon-starved tomography method due to limited optical access and signal-to-noise ratio of fast-ion D₆₅ (FIDA) spectroscopy as well as the strive for high-resolution images. In high-definition tomography, prior information makes up for this lack of data. We restrict the target velocity space through the measured absence of FIDA light, impose phase-space densities to be non-negative, and encode the known geometry of neutral beam injection (NBI) sources. We further use a numerical simulation as prior information to reconstruct where in velocity space the measurements and the simulation disagree. This alternative approach is demonstrated for four-view as well as for two-view FIDA measurements. The high-definition tomography tools allow us to study fast ions in sawtoothing plasmas and the formation of NBI peaks at full, half and one-third energy by time-resolved tomographic movies.

General information
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Organisations: Department of Physics, Plasma Physics and Fusion Energy, Department of Applied Mathematics and Computer Science, Scientific Computing, Max-Planck-Institut fur Plasmaphysik, University of California at Irvine, University of Milano Bicocca
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Noise robustness of a combined phase retrieval and reconstruction method for phase-contrast tomography

Classical reconstruction methods for phase-contrast tomography consist of two stages: phase retrieval and tomographic reconstruction. A novel algebraic method combining the two was suggested by Kostenko et al. [Opt. Express 21, 12185 (2013) [CrossRef], and preliminary results demonstrated improved reconstruction compared with a given two-stage method. Using simulated free-space propagation experiments with a single sample-detector distance, we thoroughly compare the novel method with the two-stage method to address limitations of the preliminary results. We demonstrate that the novel method is substantially more robust toward noise; our simulations point to a possible reduction in counting times by an order of magnitude.

General information
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Simultaneous Reconstruction and Segmentation with Class-Specific Priors

Studying the interior of objects using tomography often require an image segmentation, such that different material properties can be quantified. This can for example be volume or surface area. Segmentation is typically done as an image analysis step after the image has been reconstructed. This thesis investigates computing the reconstruction and segmentation simultaneously. The advantage of this is that because the reconstruction and segmentation are computed jointly, reconstruction errors are not propagated to the segmentation step. Furthermore the segmentation procedure can be used for regularizing the reconstruction process. The thesis provides models and algorithms for simultaneous reconstruction and segmentation and their performance is empirically validated.

Two method of simultaneous reconstruction and segmentation are described in the thesis. Also, a method for parameter
The reconstruction and segmentation problem is found using an algorithm that simultaneously minimizes the reprojection error, deviation of the grey levels of pixels from known mean values and the spatial differences in the class probabilities. The solution for the reconstruction and segmentation problem is found using an algorithm that simultaneously minimizes the reprojection error, deviation of the grey levels of pixels from known mean values and the spatial differences in the class probabilities.

In the first Simultaneous Reconstruction and Segmentation (SRS) method data is assumed Gaussian distributed and the minimization is done using standard optimization techniques in two stages. Experimental validation on both phantom and real data shows that modeling the reconstruction and segmentation simultaneously has superior performance, especially when the problem is underdetermined, i.e. when the number of unknowns in the reconstruction exceeds the number of observations. The second SRS method assumes Poisson distributed data, which is the case for data originating from discrete events like photon counts. The algorithm is again based on solving a minimization problem. In addition a relaxation strategy is employed in order to avoid being stuck in local minimum. This model is also validated on artificial data.

Selecting appropriate regularization parameters can be difficult, so the last thing that we consider is a parameter selection approach. The most promising approach was a modified L-curve algorithm, which was empirically analyzed.

This thesis contributes with methods for simultaneous reconstruction and segmentation and demonstrates the benefits of this approach in situations where only few projections are available and data is noisy. Here a higher precision image as well as segmentation can be computed.

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Algorithms for Electromagnetic Scattering Analysis of Electrically Large Structures
Accurate analysis of electrically large antennas is often done using either Physical Optics (PO) or Method of Moments (MoM), where the former typically requires fewer computational resources but has a limited application regime. This study has focused on fast variants of these two methods, with the goal of reducing the computational complexity while maintaining accuracy.

Regarding MoM, the complexity is reduced by applying the Multi-Level Fast Multipole Method (MLFMM) in combination with an iterative solver. Using MLFMM with a MoM implementation based on Higher-Order (HO) basis functions has, by several authors, been dismissed as being too memory intensive. In the present work, we demonstrate for the first time that by including a range of both novel and previously presented modifications to the standard MLFMM implementation, HO MLFMM can achieve both memory reduction and significant speed increase compared to Lower-Order (e.g., RWG) based MLFMM. Further, issues surrounding an iterative solution, such as the iterative solver and preconditioning, are discussed. Numerical results demonstrate the performance and stability of the algorithm for very large problems, including full satellites at Ku band.

Accelerating PO is an entirely different matter. A few authors have discussed applying the Fast-PO technique to far fields, achieving relative errors of 0.1%−1% for moderately sized scatterers. For near-fields, the state-of-the-art implementation
of Fast-PO has several difficulties, in particular low accuracy and limited application regime. For the problems considered in this thesis, the error limit for PO is ≈ 0.01%, and the application limitations of the published Fast-PO are too prohibitive for our use. Therefore, results based on an improved Fast-PO implementation for far-fields, as well as a novel algorithm for near-fields, are presented. These results demonstrate that it is possible to achieve very accurate results, with relative errors around $10^{-5}$, at a much reduced time consumption. The method behind this part of the code is deemed confidential by TICRA.

**Analysis of Electrically Large Antennas using Fast Physical Optics**

The design of electrically large antennas can be a significant challenge for computational electromagnetics (CEM) tools, particularly during the final stages of the design process where there are strict requirements for the accuracy. In the present paper, we consider the use of a newly developed accelerated Physical Optics (Fast-PO) and show that this approach allows for a timely and accurate solution of realistic designs. Several examples, ranging from canonical tests of the scaling of the method against the wavelength to real-life applications, illustrate the performance of the approach in practice.

**A Parameter Choice Method for Simultaneous Reconstruction and Segmentation**

The problem of finding good regularization parameters for the reconstruction problems without knowledge of the ground truth is a non-trivial task. We overview the existing parameterchoice methods and present the modified L-curves approach for a good regularization parameters selection that is suited for our Simultaneous Reconstruction and Segmentation method. We verify the validity of this approach with numerical experiments based on reconstructions of artificial phantoms from noisy data, and the problems in our numerical experiments are underdetermined.
Empirical average-case relation between undersampling and sparsity in X-ray CT

In X-ray computed tomography (CT) it is generally acknowledged that reconstruction methods exploiting image sparsity allow reconstruction from a significantly reduced number of projections. The use of such reconstruction methods is inspired by recent progress in compressed sensing (CS). However, the CS framework provides neither guarantees of accurate CT reconstruction, nor any relation between sparsity and a sufficient number of measurements for recovery, i.e., perfect reconstruction from noise-free data. We consider reconstruction through 1-norm minimization, as proposed in CS, from data obtained using a standard CT fan-beam sampling pattern. In empirical simulation studies we establish quantitatively a relation between the image sparsity and the sufficient number of measurements for recovery within image classes motivated by tomographic applications. We show empirically that the specific relation depends on the image class and in many cases exhibits a sharp phase transition as seen in CS, i.e., same-sparsity images require the same number of projections for recovery. Finally we demonstrate that the relation holds independently of image size and is robust to small amounts of additive Gaussian white noise.
Relaxed Simultaneous Tomographic Reconstruction and Segmentation with Class Priors for Poisson Noise

This work is a continuation of work on algorithms for simultaneous reconstruction and segmentation. In our previous work we developed an algorithm for data with Gaussian noise, and in that algorithm the coefficient matrix for the system is explicitly stored. We improve this algorithm in two ways: our new algorithm can handle Poisson noise in the data, and it can solve much larger problems since it does not store the matrix. We formulate this algorithm and test it on artificial test problems. Our results show that the algorithm performs well, and that we are able to produce reconstructions and segmentations with small errors.

Simultaneous tomographic reconstruction and segmentation with class priors

We consider tomographic imaging problems where the goal is to obtain both a reconstructed image and a corresponding segmentation. A classical approach is to first reconstruct and then segment the image; more recent approaches use a discrete tomography approach where reconstruction and segmentation are combined to produce a reconstruction that is identical to the segmentation. We consider instead a hybrid approach that simultaneously produces both a reconstructed image and segmentation. We incorporate priors about the desired classes of the segmentation through a Hidden Markov Measure Field Model, and we impose a regularization term for the spatial variation of the classes across neighboring pixels. We also present an efficient implementation of our algorithm based on state-of-the-art numerical optimization algorithms. Simulation experiments with artificial and real data demonstrate that our combined approach can produce better results than the classical two-step approach.
Reducing X-ray exposure while maintaining the image quality is a major challenge in computed tomography (CT); since the imperfect data produced from the few view and/or low intensity projections results in low-quality images that are suffering from severe artifacts when using conventional reconstruction methods. Incorporating a priori information about the solution is a necessity to improve the reconstruction. For example, Total Variation (TV) regularization method –assuming a piecewise constant image model– has been shown to allow reducing X-ray exposure significantly, while maintaining the image resolution compared to a classical reconstruction method such as Filtered Back Projection (FBP).
Some priors for the tomographic reconstruction take the form of cross-section images of similar objects, providing a set of the so-called training images, that hold the key to the structural information about the solution. The training images must be reliable and application-specific. This PhD project aims at providing a mathematical and computational framework for the use of training sets as non-parametric priors for the solution in tomographic image reconstruction. Through an unsupervised machine learning technique (here, the dictionary learning), prototype elements from the training images are extracted and then incorporated in the tomographic reconstruction problem both with matrix and tensor representations of the training images.

First, an algorithm for the tomographic image reconstruction using training images, where the training images are represented as vectors in a training matrix, is described. The dictionary learning problem is formulated as a regularized non-negative matrix factorization in order to compute a nonnegative dictionary. Then a tomographic solution with a sparse representation in the dictionary is obtained through a convex optimization formulation. Computational experiments clarify the choice and interplay of the model parameters and the regularization parameters. Furthermore, the assumptions in the tomographic problem formulation are analyzed. The sensitivity and robustness of the reconstruction to variations of the scale and rotation in the training images is investigated and algorithms to estimate the correct relative scale and orientation of the unknown image to the training images are suggested.

Then, a third-order tensor representation for the training images images is used. The dictionary and image reconstruction problem are reformulated using the tensor representation. The dictionary learning problem is presented as a nonnegative tensor factorization problem with sparsity constraints and the reconstruction problem is formulated in a convex optimization framework by looking for a solution with a sparse representation in the tensor dictionary. Numerical results show considering a tensor formulation over a matrix formulation significantly reduces the approximation error by the dictionary as well as leads to very sparse representations of both the training images and the reconstructions.

Further computational experiments show that in few-projection and low-dose settings our algorithm is while (not surprisingly) being superior to the classical reconstruction methods, is competitive with (or even better of) the TV regularization and tends to include more texture and sharper edges in the reconstructed images.

The focus of the thesis is the study of mathematical and algorithmic prospectives and thus the training images and tomographic scenarios are mostly simulation based. More studies are however needed for implementing the proposed algorithm in a routine use for clinical applications and materials testing.

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A computationally efficient tool for assessing the depth resolution in large-scale potential-field inversion
In potential-field inversion, careful management of singular value decomposition components is crucial for obtaining information about the source distribution with respect to depth. In principle, the depth-resolution plot provides a convenient visual tool for this analysis, but its computational complexity has hitherto prevented application to large-scale problems. To analyze depth resolution in such problems, we developed a variant ApproxDRP, which is based on an iterative algorithm and therefore suited for large-scale problems because we avoid matrix factorizations and the associated demands on memory and computing time. We used the ApproxDRP to study retrievable depth resolution in inversion of the gravity field of the Neapolitan Volcanic Area. Our main contribution is the combined use of the Lanczos bidiagonalization algorithm, established in the scientific computing community, and the depth-resolution plot defined in the geoscience community.

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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, University of Naples Federico II, Technical University of Denmark
A Computationally Efficient Tool for Assessing the Depth Resolution in Potential-Field Inversion

In potential-field inversion problems, it can be difficult to obtain reliable information about the source distribution with respect to depth. Moreover, spatial resolution of the reconstructions decreases with depth, and in fact the more ill-posed the problem - and the more noisy the data - the less reliable the depth information. Based on earlier work using the singular value decomposition, we introduce a tool ApproxDRP which uses approximations of the singular vectors obtained by the iterative Lanczos bidiagonalization algorithm, making it well suited for large-scale problems. This tool allows a computational/visual analysis of how much the depth resolution in a computational potential-field inversion problem can be obtained from the given data. Through synthetic and real data examples we demonstrate that ApproxDRP, when used in combination with a plot of the approximate SVD quantities, may successfully show the limitations of depth resolution resulting from noise in the data. This allows a reliable analysis of the retrievable depth information and effectively guides the user in choosing the optimal number of iterations, for a given problem.

Adaptive grouping for the higher-order multilevel fast multipole method

An alternative parameter-free adaptive approach for the grouping of the basis function patterns in the multilevel fast multipole method is presented, yielding significant memory savings compared to the traditional Octree grouping for most discretizations, particularly when using higher-order basis functions. Results from both a uniformly and nonuniformly meshed scatterer are presented, showing how the technique is worthwhile even for regular meshes, and demonstrating that there is no loss of accuracy in spite of the large reduction in memory requirements and the relatively low computational cost.
Gaussian translation operator for Multi-Level Fast Multipole Method

Results using a new translation operator for the Multi-Level Fast Multipole Method are presented. Based on Gaussian beams, the translation operator allows a significant portion of the plane-wave directions to be neglected, resulting in a much faster translation step.
Generalized Row-Action Methods for Tomographic Imaging

Row-action methods play an important role in tomographic image reconstruction. Many such methods can be viewed as incremental gradient methods for minimizing a sum of a large number of convex functions, and despite their relatively poor global rate of convergence, these methods often exhibit fast initial convergence which is desirable in applications where a low-accuracy solution is acceptable. In this paper, we propose relaxed variants of a class of incremental proximal gradient methods, and these variants generalize many existing row-action methods for tomographic imaging. Moreover, they allow us to derive new incremental algorithms for tomographic imaging that incorporate different types of prior information via regularization. We demonstrate the efficacy of the approach with some numerical examples.
Improved Multilevel Fast Multipole Method for Higher-Order discretizations

The Multilevel Fast Multipole Method (MLFMM) allows for a reduced computational complexity when solving electromagnetic scattering problems. Combining this with the reduced number of unknowns provided by Higher-Order discretizations has proven to be a difficult task, with the general conclusion being that going above 2nd order is not worthwhile. In this paper, we challenge this conclusion, providing results that demonstrate the potential performance gains with Higher-Order MLFMM and showing some modifications to the traditional MLFMM that can benefit both Higher-Order and standard discretizations.

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Multicore Performance of Block Algebraic Iterative Reconstruction Methods

Algebraic iterative methods are routinely used for solving the ill-posed sparse linear systems arising in tomographic image reconstruction. Here we consider the algebraic reconstruction technique (ART) and the simultaneous iterative reconstruction techniques (SIRT), both of which rely on semiconvergence. Block versions of these methods, based on a partitioning of the linear system, are able to combine the fast semiconvergence of ART with the better multicore properties of SIRT. These block methods separate into two classes: those that, in each iteration, access the blocks in a sequential manner, and those that compute a result for each block in parallel and then combine these results before the next iteration. The goal of this work is to demonstrate which block methods are best suited for implementation on modern multicore computers. To compare the performance of the different block methods, we use a fixed relaxation parameter in each method, namely, the one that leads to the fastest semiconvergence. Computational results show that for multicore computers, the sequential approach is preferable.
Multilevel Fast Multipole Method for Higher Order Discretizations

The multi-level fast multipole method (MLFMM) for a higher order (HO) discretization is demonstrated on high-frequency (HF) problems, illustrating for the first time how an efficient MLFMM for HO can be achieved even for very large groups. Applying several novel ideas, beneficial to both lower order and higher order discretizations, results from a low-memory, high-speed MLFMM implementation of a HO hierarchical discretization are shown. These results challenge the general view that the benefits of HO and HF-MLFMM cannot be combined.

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BFI (2014): BFI-level 2
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**Plug-and-play** edge-preserving regularization

In many inverse problems it is essential to use regularization methods that preserve edges in the reconstructions, and many reconstruction models have been developed for this task, such as the Total Variation (TV) approach. The associated algorithms are complex and require a good knowledge of large-scale optimization algorithms, and they involve certain tolerances that the user must choose. We present a simpler approach that relies only on standard computational building blocks in matrix computations, such as orthogonal transformations, preconditioned iterative solvers, Kronecker products, and the discrete cosine transform. Hence the term "plug-and-play". We do not attempt to improve on TV reconstructions, but rather provide an easy-to-use approach to computing reconstructions with similar properties.

**General information**

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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Southwestern University of Finance and Economics, Tufts University
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R3GMRES: including prior information in GMRES-type methods for discrete inverse problems

Lothar Reichel and his collaborators proposed several iterative algorithms that augment the underlying Krylov subspace with an additional low-dimensional subspace in order to produce improved regularized solutions. We take a closer look at this approach and investigate a particular Regularized Range-Restricted GMRES method, R3GMRES, with a subspace that represents prior information about the solution. We discuss the implementation of this approach and demonstrate its advantage by means of several test problems.
Reflector antenna analysis using physical optics on Graphics Processing Units
The Physical Optics approximation is a widely used asymptotic method for calculating the scattering from electrically large bodies. It requires significant computational work and little memory, and is thus well suited for application on a Graphics Processing Unit. Here, we investigate the performance of an implementation and demonstrate that while there are some implementational pitfalls, a careful implementation can result in impressive improvements.

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Authors: Borries, O. P. (Intern), Sørensen, H. H. B. (Intern), Dammann, B. (Intern), Jorgensen, E. (Intern), Meincke, P. (Intern), Sorensen, S. B. (Ekstern), Hansen, P. C. (Intern)
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Rotational image deblurring with sparse matrices
We describe iterative deblurring algorithms that can handle blur caused by a rotation along an arbitrary axis (including the common case of pure rotation). Our algorithms use a sparse-matrix representation of the blurring operation, which allows us to easily handle several different boundary conditions. We also include robust stopping rules for the iterations. The performance of our algorithms is illustrated with examples.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Emory University, Fraunhofer Gesellschaft
Authors: Hansen, P. C. (Intern), Nagy, J. G. (Ekstern), Tigkos, K. (Intern)
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BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.044 SNIP 1.208 CiteScore 1.01
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Kaczmarz’s method—sometimes referred to as the algebraic reconstruction technique—is an iterative method that is widely used in tomographic imaging due to its favorable semi-convergence properties. Specifically, when applied to a problem with noisy data, during the early iterations it converges very quickly toward a good approximation of the exact solution, and thus produces a regularized solution. While this property is generally accepted and utilized, there is surprisingly little theoretical justification for it. The purpose of this paper is to present insight into the semi-convergence of Kaczmarz’s method as well as its projected counterpart (and their block versions). To do this we study how the data errors propagate into the iteration vectors and we derive upper bounds for this noise propagation. Our bounds are compared with numerical results obtained from tomographic imaging.

**Semi-convergence properties of Kaczmarz’s method**

Kaczmarz’s method—sometimes referred to as the algebraic reconstruction technique—is an iterative method that is widely used in tomographic imaging due to its favorable semi-convergence properties. Specifically, when applied to a problem with noisy data, during the early iterations it converges very quickly toward a good approximation of the exact solution, and thus produces a regularized solution. While this property is generally accepted and utilized, there is surprisingly little theoretical justification for it. The purpose of this paper is to present insight into the semi-convergence of Kaczmarz’s method as well as its projected counterpart (and their block versions). To do this we study how the data errors propagate into the iteration vectors and we derive upper bounds for this noise propagation. Our bounds are compared with numerical results obtained from tomographic imaging.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Linköping University, Iran University of Science and Technology
Authors: Elfving, T. (Ekstern), Hansen, P. C. (Intern), Nikazad, T. (Ekstern)
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Inverse Problems in Geosciences: Modelling the Rock Properties of an Oil Reservoir

Even the most optimistic forecasts predict that Danish oil production will decrease by 80% in the period between 2006 and 2040, and only a strong innovative technological effort can change that. Due to the geological structures of the subsurface in the Danish part of the North Sea, Denmark is currently missing out on approximately 70% of the oil, which is left behind, trapped in unreachable parts of the reservoirs.

An increase in the oil recovery rate can be achieved by better planning and optimisation of oil production. Both require an improved description of the rock properties of the subsurface of the reservoirs. Hence the focus of this work has been on acquiring models of spatial parameters describing rock properties of the subsurface using geostatistical a priori knowledge
and available geophysical data. Such models are solutions to often severely under-determined, inverse problems.

The focus of the study has been on the computational aspects of inferring such models. Reservoir modelling is a large-

scale problem with great computational complexity and the work should be seen as a first part of a foundation for one day,

when the computational resources are available, being able to handle the large scale problems of the petroleum industry.

But for now most of the study is based on simplified and idealised models.

We have proposed a method for efficient and accurate interpolation of rock properties from seismic data. It is based on a

recently published paper on interpolation of rock properties that breaks with the dominating influence of spatial coordinates

in traditional interpolation methods. The thesis contains work involving a test case study of the method demonstrating how

the interpolation in attribute space ensures the geological structures of the computed models and how the method can be

further improved by an orthogonal transformation of the attribute space.

We have formulated a closed form expression of an a priori probability density function that quantifies the statistical

probability of models describing the rock properties of a reservoir. This can be used to evaluate the probability that a

model adhere to prior knowledge by having specific multiple-point statistics, for instance, learned from a training image.

Existing methods efficiently sample an a priori probability density function to create a set of acceptable models; but they

cannot evaluate the probability of a model.

We have developed and implemented the Frequency Matching method that uses the closed form expression of the a priori

probability density function to formulate an inverse problem and compute the maximum a posteriori solution to it. Other

methods for computing models that simultaneously fit data observations and honour a priori knowledge are not capable of

computing the maximum a posteriori solution. Instead they either sample the posterior probability density function or they

sample the a priori probability density function to optimise the likelihood function.

This thesis consists of a summary report and seven research papers submitted, reviewed and/or published in the period

2010 - 2013.

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Organisations: Center for Energy Resources Engineering, Department of Applied Mathematics and Computer Science ,
Scientific Computing, Department of Chemistry
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Least Squares Data Fitting with Applications
As one of the classical statistical regression techniques, and often the first to be taught to new students, least squares
fitting can be a very effective tool in data analysis. Given measured data, we establish a relationship between independent
and dependent variables so that we can use the data predictively. The main concern of Least Squares Data Fitting with
Applications is how to do this on a computer with efficient and robust computational methods for linear and nonlinear
relationships. The presentation also establishes a link between the statistical setting and the computational issues.

In a number of applications, the accuracy and efficiency of the least squares fit is central, and Per Christian Hansen, Víctor
Pereyra, and Godela Scherer survey modern computational methods and illustrate them in fields ranging from engineering
and environmental sciences to geophysics. Anyone working with problems of linear and nonlinear least squares fitting will
find this book invaluable as a hands-on guide, with accessible text and carefully explained problems.

Included are
• an overview of computational methods together with their properties and advantages
• topics from statistical regression analysis that help readers to understand and evaluate the computed solutions
• many examples that illustrate the techniques and algorithms
Least Squares Data Fitting with Applications can be used as a textbook for advanced undergraduate or graduate courses and professionals in the sciences and in engineering.

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Oblique projections and standard-form transformations for discrete inverse problems
This tutorial paper considers a specific computational tool for the numerical solution of discrete inverse problems, known as the standard-form transformation, by which we can treat general Tikhonov regularization problems efficiently. In the tradition of B. N. Datta's expositions of numerical linear algebra, we use the close relationship between oblique projections, pseudoinverses, and matrix computations to derive a simple geometric motivation and algebraic formulation of the standard-form transformation.

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BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.209 SNIP 1.461 CiteScore 1.28
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Web of Science (2013): Indexed yes
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Scopus rating (2012): SJR 0.839 SNIP 1.321 CiteScore 1.06
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ISI indexed (2011): ISI indexed yes
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Sparse Image Reconstruction in Computed Tomography

In recent years, increased focus on the potentially harmful effects of x-ray computed tomography (CT) scans, such as radiation-induced cancer, has motivated research on new low-dose imaging techniques. Sparse image reconstruction methods, as studied for instance in the field of compressed sensing (CS), have shown significant empirical potential for this purpose. For example, total variation regularized image reconstruction has been shown in some cases to allow reducing x-ray exposure by a factor of 10 or more, while maintaining or even improving image quality compared to conventional reconstruction methods.

However, the potential in CT has mainly been demonstrated in individual proof-of-concept studies, from which it is hard to distill general conditions for when sparse reconstruction methods perform well. As a result, there is a fundamental lack of understanding of the effectiveness and limitations of sparse reconstruction methods in CT, in particular in a quantitative sense. For example, relations between image properties such as contrast, structure and sparsity, tolerable noise levels, sufficient sampling levels, the choice of sparse reconstruction formulation and the achievable image quality remain unclear. This is a problem of high practical concern, because the large scale of CT problems makes detailed exploration of the parameter space very time-consuming. Due to the limited quantitative understanding, sparse reconstruction has not yet become the method of choice in practical CT applications.

This thesis takes a systematic approach toward establishing quantitative understanding of conditions for sparse reconstruction to work well in CT. A general framework for analyzing sparse reconstruction methods in CT is introduced and two sets of computational tools are proposed:

1. An optimization algorithm framework enabling easy derivation of algorithms for sparse reconstruction problems, and
2. Tools for characterizing sparse reconstruction in CT, i.e., establishing relations between parameters governing reconstruction quality.

The flexibility of the optimization algorithm framework is demonstrated by constructing convergent optimization algorithms for a range of sparse reconstruction problems of interest to CT. The practical usefulness of the framework is shown through case studies of the effectiveness of specic sparse reconstruction problems in tomographic reconstruction.

The characterization methods proposed in the thesis focus on the role of image sparsity for the level of sampling required for accurate CT reconstruction. While a relation between sparsity and sampling is motivated by CS, no theoretical guarantees of accurate sparse reconstruction are known for CT. In simulation studies, a sparsity-sampling relation is established in CT. This enables quantification of the undersampling allowed by sparse reconstruction methods.

Both the prototyping framework and the characterization methods add to the understanding of sparse reconstruction methods in CT and serve as initial contributions to a general set of computational characterization tools. Thus, the thesis contributions help advance sparse reconstruction methods toward routine use in

General information
The overall topic of this thesis is convex conic optimization, a sub-field of mathematical optimization that attacks optimization problem with a certain geometric structure. These problems allow for modelling of an extremely wide range of real-world problems, but the availability of solution algorithms for these problems is still limited.

The goal of this thesis is to investigate and shed light on two computational aspects of homogeneous interior-point algorithms for convex conic optimization:
The first part studies the possibility of devising a homogeneous interior-point method aimed at solving problems involving constraints that require nonsymmetric cones in their formulation. The second part studies the possibility of warmstarting the homogeneous interior-point algorithm for conic problems. The main outcome of the first part is the introduction of a completely new homogeneous interior-point algorithm designed to solve nonsymmetric convex conic optimization problems. The algorithm is presented in detail and then analyzed. We prove its convergence and complexity. From a theoretical viewpoint, it is fully competitive with other algorithms and from a practical viewpoint, we show that it holds lots of potential, in several cases being superior to other solution methods.

The main outcome of the second part of the thesis is two new warmstarting schemes for the homogeneous interior-point algorithm for conic problems. Again, we first motivate and present the schemes and then analyze them. It is proved that they, under certain circumstances, result in an improved worst-case complexity as compared to a normal coldstart. We then move on to present an extensive series of computational results substantiating the practical usefulness of these warmstarting schemes. These experiments include standard benchmarking problem test sets as well as an application from smart energy systems.

AIR Tools - A MATLAB package of algebraic iterative reconstruction methods
We present a MATLAB package with implementations of several algebraic iterative reconstruction methods for discretizations of inverse problems. These so-called row action methods rely on semi-convergence for achieving the
necessary regularization of the problem. Two classes of methods are implemented: Algebraic Reconstruction Techniques (ART) and Simultaneous Iterative Reconstruction Techniques (SIRT). In addition we provide a few simplified test problems from medical and seismic tomography. For each iterative method, a number of strategies are available for choosing the relaxation parameter and the stopping rule. The relaxation parameter can be fixed, or chosen adaptively in each iteration; in the former case we provide a new “training” algorithm that finds the optimal parameter for a given test problem. The stopping rules provided are the discrepancy principle, the monotone error rule, and the NCP criterion; for the first two methods “training” can be used to find the optimal discrepancy parameter.

General information
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Authors: Hansen, P. C. (Intern), Saxild-Hansen, M. (Ekstern)
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Scopus rating (2013): SJR 1.137 SNIP 1.483 CiteScore 1.44
ISI indexed (2013): ISI indexed yes
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Scopus rating (2012): SJR 0.984 SNIP 1.375 CiteScore 1.38
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.02 SNIP 1.386 CiteScore 1.44
ISI indexed (2011): ISI indexed yes
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Scopus rating (2010): SJR 0.927 SNIP 1.247
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Scopus rating (2009): SJR 0.803 SNIP 1.34
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Scopus rating (2008): SJR 0.859 SNIP 1.27
Scopus rating (2007): SJR 0.882 SNIP 1.396
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.747 SNIP 1.099
Scopus rating (2005): SJR 0.793 SNIP 1.099
Scopus rating (2004): SJR 0.719 SNIP 0.995
Scopus rating (2003): SJR 0.828 SNIP 1.194
Scopus rating (2002): SJR 0.881 SNIP 1.01
Scopus rating (2001): SJR 0.77 SNIP 0.94
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Electrical Impedance Tomography: 3D Reconstructions using Scattering Transforms

In three dimensions the Calderon problem was addressed and solved in theory in the 1980s. The main ingredients in the solution of the problem are complex geometrical optics solutions to the conductivity equation and a (non-physical) scattering transform. The resulting reconstruction algorithm is in principle direct and addresses the full non-linear problem immediately. In this paper a new simplication of the algorithm is suggested. The method is based on solving a boundary integral equation for the complex geometrical optics solutions, and the method is implemented numerically using a Nystrom method. Convergence estimates are obtained using hyperinterpolation operators. We compare the method numerically to two other approximations by evaluation on two numerical examples. In addition a moment method for the numerical solution of the forward problem is given.
We present a practical implementation of an optimal first-order method, due to Nesterov, for large-scale total variation regularization in tomographic reconstruction, image deblurring, etc. The algorithm applies to $\mu$-strongly convex objective functions with $L$-Lipschitz continuous gradient. In the framework of Nesterov both $\mu$ and $L$ are assumed known—an assumption that is seldom satisfied in practice. We propose to incorporate mechanisms to estimate locally sufficient $\mu$ and $L$ during the iterations. The mechanisms also allow for the application to non-strongly convex functions. We discuss the convergence rate and iteration complexity of several first-order methods, including the proposed algorithm, and we use a 3D tomography problem to compare the performance of these methods. In numerical simulations we demonstrate the advantage in terms of faster convergence when estimating the strong convexity parameter $\mu$ for solving ill-conditioned problems to high accuracy, in comparison with an optimal method for non-strongly convex problems and a first-order method with Barzilai-Borwein step size selection.
Quantitative study of undersampled recoverability for sparse images in computed tomography

Image reconstruction methods based on exploiting image sparsity, motivated by compressed sensing (CS), allow reconstruction from a significantly reduced number of projections in X-ray computed tomography (CT). However, CS provides neither theoretical guarantees of accurate CT reconstruction, nor any relation between sparsity and a sufficient number of measurements for recovery. In this paper, we demonstrate empirically through computer simulations that minimization of the image 1-norm allows for recovery of sparse images from fewer measurements than unknown pixels, without relying on artificial random sampling patterns. We establish quantitatively an average-case relation between image sparsity and sufficient number of measurements for recovery, and we show that the transition from non-recovery to recovery is sharp within well-defined classes of simple and semi-realistic test images. The specific behavior depends on the type of image, but the same quantitative relation holds independently of image size.

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Authors: Jørgensen, J. H. (Intern), Sidky, E. Y. (Ekstern), Hansen, P. C. (Intern), Pan, X. (Ekstern)
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Semiconvergence and Relaxation Parameters for Projected SIRT Algorithms
We give a detailed study of the semiconvergence behavior of projected nonstationary simultaneous iterative reconstruction technique (SIRT) algorithms, including the projected Landweber algorithm. We also consider the use of a relaxation parameter strategy, proposed recently for the standard algorithms, for controlling the semiconvergence of the projected algorithms. We demonstrate the semiconvergence and the performance of our strategies by examples taken from tomographic imaging. © 2012 Society for Industrial and Applied Mathematics.

General information
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Organisations: Department of Informatics and Mathematical Modeling, Scientific Computing, Linköping University, Iran University of Science and Technology
Authors: Elfving, T. (Ekstern), Hansen, P. C. (Intern), Nikazad, T. (Ekstern)
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BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.955 SNIP 1.795 CiteScore 2.3
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BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.932 SNIP 2.017 CiteScore 2.43
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.986 SNIP 2.165 CiteScore 2.72
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.74 SNIP 1.77 CiteScore 2.19
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.618 SNIP 1.582 CiteScore 2.23
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.65 SNIP 1.768
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.092 SNIP 1.883
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.668 SNIP 1.624
Scopus rating (2007): SJR 1.782 SNIP 1.897
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 2.139 SNIP 2.691
Scopus rating (2005): SJR 2.318 SNIP 2.19
Scopus rating (2004): SJR 1.958 SNIP 1.728
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.843 SNIP 2.032
Accelerated gradient methods for total-variation-based CT image reconstruction

Total-variation (TV)-based CT image reconstruction has shown experimentally to be capable of producing accurate reconstructions from sparse-view data. In particular TV-based reconstruction is very well suited for images with piecewise nearly constant regions. Computationally, however, TV-based reconstruction is much more demanding, especially for 3D imaging, and the reconstruction from clinical data sets is far from being close to real-time. This is undesirable from a clinical perspective, and thus there is an incentive to accelerate the solution of the underlying optimization problem. The TV reconstruction can in principle be found by any optimization method, but in practice the large scale of the systems arising in CT image reconstruction preclude the use of memory-demanding methods such as Newton’s method. The simple gradient method has much lower memory requirements, but exhibits slow convergence. In the present work we address the question of how to reduce the number of gradient method iterations needed to achieve a high-accuracy TV reconstruction. We consider the use of two accelerated gradient-based methods, GPBB and UPN, to solve the 3D-TV minimization problem in CT image reconstruction. The former incorporates several heuristics from the optimization literature such as Barzilai-Borwein (BB) step size selection and nonmonotone line search. The latter uses a cleverly chosen sequence of auxiliary points to achieve a better convergence rate. The methods are memory efficient and equipped with a stopping criterion to ensure that the TV reconstruction has indeed been found. An implementation of the methods (in C with interface to Matlab) is available for download from http://www2.imm.dtu.dk/pch/TVReg/. We compare the proposed methods with the standard gradient method, applied to a 3D test problem with synthetic few-view data. We find experimentally that for realistic parameters the proposed methods significantly outperform the gradient method.

A Direct Numerical Reconstruction Algorithm for the 3D Calderón Problem

In three dimensions Calderón's problem was addressed and solved in theory in the 1980s in a series of papers, but only recently the numerical implementation of the algorithm was initiated. The main ingredients in the solution of the problem are complex geometrical optics solutions to the conductivity equation and a (non-physical) scattering transform. The resulting reconstruction algorithm is in principle direct and addresses the full non-linear problem immediately. In this paper we will outline the theoretical reconstruction method and describe how the method can be implemented numerically. We will give three different implementations, and compare their performance on a numerical phantom.
Image Deblurring with Krylov Subspace Methods

Image deblurring, i.e., reconstruction of a sharper image from a blurred and noisy one, involves the solution of a large and very ill-conditioned system of linear equations, and regularization is needed in order to compute a stable solution. Krylov subspace methods are often ideally suited for this task: their iterative nature is a natural way to handle such large-scale
problems, and the underlying Krylov subspace provides a convenient mechanism to regularized the problem by projecting it onto a low-dimensional "signal subspace" adapted to the particular problem. In this talk we consider the three Krylov subspace methods CGLS, MINRES, and GMRES. We describe their regularizing properties, and we discuss some computational aspects such as preconditioning and stopping criteria.

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Source: orbit
Source-ID: 286356
Publication: Research - peer-review › Article in proceedings – Annual report year: 2011

**On Implementing a Homogeneous Interior-Point Algorithm for Nonsymmetric Conic Optimization**
Based on earlier work by Nesterov, an implementation of a homogeneous infeasible-start interior-point algorithm for solving nonsymmetric conic optimization problems is presented. Starting each iteration from (the vicinity of) the central path, the method computes (nearly) primal-dual symmetric approximate tangent directions followed by a purely primal centering procedure to locate the next central primal-dual point. Features of the algorithm include that it makes use only of the primal barrier function, that it is able to detect infeasibilities in the problem and that no phase-I method is needed. The method further employs quasi-Newton updating both to generate (pseudo) higher order directions and to reduce the number of factorizations needed in the centering process while still retaining the ability to exploit sparsity. Extensive and promising computational results are presented for the p-cone problem, the facility location problem, entropy problems and geometric programs; all formulated as nonsymmetric conic optimization problems.

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**Total Variation and Tomographic Imaging from Projections**
Total Variation (TV) regularization is a powerful technique for image reconstruction tasks such as denoising, inpainting, and deblurring, because of its ability to produce sharp edges in the images. In this talk we discuss the use of TV regularization for tomographic imaging, where we compute a 2D or 3D reconstruction from noisy projections. We demonstrate that for a small signal-to-noise ratio, this new approach allows us to compute better (i.e., more reliable) reconstructions than those obtained by classical methods. This is possible due to the use of the TV reconstruction model, which incorporates our prior information about the solution and thus compensates for the loss of accuracy in the data. A consequence is that smaller data acquisition times can be used, thus reducing a patients exposure to X-rays in medical scanning and speeding up non-destructive measurements in materials science.

**General information**
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Toward optimal X-ray flux utilization in breast CT
A realistic computer-simulation of a breast computed tomography (CT) system and subject is constructed. The model is used to investigate the optimal number of views for the scan given a fixed total X-ray fluence. The reconstruction algorithm is based on accurate solution to a constrained, TVminimization problem, which has received much interest recently for sparse-view CT data.

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Authors: Jørgensen, J. H. (Intern), Hansen, P. C. (Intern), Sidky, E. Y. (Ekstern), Reiser, I. S. (Ekstern), Pan, X. (Ekstern)
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AIR Tools - A MATLAB Package of Algebraic Iterative Reconstruction Techniques: Version 1.0 for Matlab 7.8

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Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Saxild-Hansen, M. (Ekstern)
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Algorithms and software for total variation image reconstruction via first-order methods
This paper describes new algorithms and related software for total variation (TV) image reconstruction, more specifically: denoising, inpainting, and deblurring. The algorithms are based on one of Nesterov's first-order methods, tailored to the image processing applications in such a way that, except for the mandatory regularization parameter, the user needs not specify any parameters in the algorithms. The software is written in C with interface to Matlab (version 7.5 or later), and we demonstrate its performance and use with examples.
Semi-convergence and relaxation parameters for a class of SIRT algorithms

This paper is concerned with the Simultaneous Iterative Reconstruction Technique (SIRT) class of iterative methods for solving inverse problems. Based on a careful analysis of the semi-convergence behavior of these methods, we propose two new techniques to specify the relaxation parameters adaptively during the iterations, so as to control the propagated noise component of the error. The advantage of using this strategy for the choice of relaxation parameters on noisy and ill-conditioned problems is demonstrated with an example from tomography (image reconstruction from projections).
Towards multi-exponential analysis in optically stimulated luminescence

Optically stimulated luminescence (OSL) data from quartz can follow different mathematical forms depending on the stimulation mode. These data can be described in terms of different multi-exponential models and can be numerically fitted using several well-known methods. Here we make a comparative analysis of the performance and stability of two models, the decay and peak form, and we consider different transformation methods for obtaining the peak form. For the numerical computations we use a nonlinear least squares (NLS) method and a method based on a first-kind Fredholm integral equation (FIE). Our analysis uses artificial data with three components (seven parameters including the background) and ten different levels of background, both the signal and the background contain Poisson distributed noise. Parameters derived using both models are acceptable (statistically consistent and on an average within similar to 1% of the expected value) and no obvious preference is observed for any particular model, although there may be a suggestion that peak-form data show a smaller mean bias. This conclusion seems to be independent of the type of peak transformations investigated here. Furthermore, it is found that transformation of OSL decay data to a peak form gives better results than direct measurement of peak-form data by, for example, varying the stimulation light intensity. The comparison of the two numerical methods suggests that the NLS method performs somewhat better than the FIE method; however, the latter has the advantage that it does not require the user's judgement on the number of components in the data. Testing of the NLS procedure on a measured quartz time-resolved OSL signal transformed into peak form yielded reliable parameter estimates even when the signal intensity was deliberately reduced by a factor of 16.
TVReg

"TVReg" is a software package for 3D tomography using Total Variation regularization. The work was carried out as part of the project CSI: Computational Science in Imaging, funded by the Danish Research Council for Technology and Production Sciences, and headed by Prof. Per Christian Hansen, DTU Informatics. The collaborators are DTU Informatics, Dept. of Electronic Systems at Aalborg University, and MOSEK ApS. The main algorithm (UPN) is our practical implementation of an optimal first-order method for strongly convex functions, due to Nesterov, tailored to large-scale total variation regularization. Nesterov's algorithm requires knowledge of both the Lipschitz constant and the strong convexity parameter, both of which are usually unknown, and our implementation incorporates mechanisms to estimate these important parameters during the iterations - thus making the algorithm suited for practical use. The package also includes two other first-order methods: a method by Nesterov, Beck, and Teboulle (UPN_0) for the case of a zero strong convexity parameter, and the Barzilai-Borwein accelerated gradient projection method (GPBB).

Two Exponential Models for Optically Stimulated Luminescence

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Authors: Hansen, P. C. (Intern), Nielsen, H. B. (Intern), Ankjærgaard, C. (Intern), Jain, M. (Intern)
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Numerical Approximation of Boundary Control for the Wave Equation - with Application to an Inverse Problem

We consider a control problem for the wave equation: Given the initial state, find a specific boundary condition, called a control, that steers the system to a desired final state. The Hilbert uniqueness method (HUM) is a mathematical method for the solution of such control problems. It builds on the duality between the control system and its adjoint system, and these systems are connected via a so-called controllability operator. In this project, we are concerned with the numerical approximation of HUM control for the one-dimensional wave equation. We study two semi-discretizations of the wave equation: a linear finite element method (L-FEM) and a discontinuous Galerkin-FEM (DG-FEM). The controllability operator is discretized with both L-FEM and DG-FEM to obtain a HUM matrix. We show that formulating HUM in a sine
basis is beneficial for several reasons: (i) separation of low and high frequency waves, (ii) close connection to the dispersive relation, (iii) simple and effective filtering. The dispersive behavior of a discretization is very important for its ability to solve control problems. We demonstrate that the group velocity is determining for a scheme’s success in relation to HUM. The vanishing group velocity for high wavenumbers results in a dramatic decay of the corresponding eigenvalues of the HUM matrix and thereby also in a huge condition number. We show that, provided sufficient filtering, the phase velocity decides the accuracy of the computed controls. DG-FEM shows very suitable for the treatment of control problems. The good dispersive behavior is an important virtue and a decisive factor in the success over L-FEM. Increasing the order of DG-FEM even give results of spectral accuracy. The field of control is closely related to other fields of mathematics among these are inverse problems. As an example, we employ a HUM solution to an inverse source problem for the wave equation: Given boundary measurements for a wave problem with a separable source, find the spatial part of the source term. The reconstruction formula depends on a set of HUM eigenfunction controls; we suggest a discretization and show its convergence. We compare results obtained by L-FEM controls and DG-FEM controls. The reconstruction formula is seen to be quite sensitive to control inaccuracies which indeed favors DG-FEM over L-FEM.

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Organisations: Applied functional analysis, Department of Mathematics, Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Mariegaard, J. S. (Intern), Knudsen, K. (Intern), Hansen, P. C. (Intern), Pedersen, M. (Intern)
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A hybrid method for the parallel computation of Green's functions
Quantum transport models for nanodevices using the non-equilibrium Green's function method require the repeated calculation of the block tridiagonal part of the Green's and lesser Green's function matrices. This problem is related to the calculation of the inverse of a sparse matrix. Because of the large number of times this calculation needs to be performed, this is computationally very expensive even on supercomputers. The classical approach is based on recurrence formulas which cannot be efficiently parallelized. This practically prevents the solution of large problems with hundreds of thousands of atoms. We propose new recurrences for a general class of sparse matrices to calculate Green's and lesser Green's function matrices which extend formulas derived by Takahashi and others. We show that these recurrences may lead to a dramatically reduced computational cost because they only require computing a small number of entries of the inverse matrix. Then, we propose a parallelization strategy for block tridiagonal matrices which involves a combination of Schur complement calculations and cyclic reduction. It achieves good scalability even on problems of modest size.

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Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Stanford University, University of Copenhagen, Aarhus University
Authors: Petersen, D. E. (Ekstern), Li, S. (Ekstern), Stokbro, K. (Ekstern), Sørensen, H. H. B. (Intern), Hansen, P. C. (Intern), Skelboe, S. (Ekstern), Darve, E. (Ekstern)
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Closing the gap between single crystal and powder diffraction

General information
Efficient wave-function matching approach for quantum transport calculations

The wave-function matching (WFM) technique has recently been developed for the calculation of electronic transport in quantum two-probe systems. In terms of efficiency it is comparable to the widely used Green’s function approach. The WFM formalism presented so far requires the evaluation of all the propagating and evanescent bulk modes of the left and right electrodes in order to obtain the correct coupling between device and electrode regions. In this paper we will describe a modified WFM approach that allows for the exclusion of the vast majority of the evanescent modes in all parts of the calculation. This approach makes it feasible to apply iterative techniques to efficiently determine the few required bulk modes, which allows for a significant reduction of the computational expense of the WFM method. We illustrate the efficiency of the method on a carbon nanotube field-effect-transistor device displaying band-to-band tunneling and modeled within the semiempirical extended Hückel theory framework.
Integrated intensities based on grain orientation distribution functions

General information
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Organisations: Metal Structures in Four Dimensions, Materials Research Division, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, H. O. (Intern), Wright, J. (Ekstern), Schmidt, S. (Intern), Hansen, P. C. (Intern), Poulsen, H. F. (Intern)
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Matematikken i computerens verden - computeren i matematikkens tjeneste

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Reconstruction of Single-Grain Orientation Distribution Functions for Crystalline Materials

A fundamental imaging problem in microstructural analysis of metals is the reconstruction of local crystallographic orientations from X-ray diffraction measurements. This work develops a fast, accurate, and robust method for the computation of the three-dimensional orientation distribution function for individual grains of the material in consideration. We study two iterative large-scale reconstruction algorithms, the algebraic reconstruction technique (ART) and conjugate gradients for least squares (CGLS), and demonstrate that right preconditioning is necessary in both algorithms to provide satisfactory reconstructions. Our right preconditioner is not a traditional one that accelerates convergence; its purpose is to modify the smoothness properties of the reconstruction. We also show that a new stopping criterion, based on the information available in the residual vector, provides a robust choice of the number of iterations for these preconditioned methods.

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  BFI (2015): BFI-level 2
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  Web of Science (2015): Indexed yes
  BFI (2014): BFI-level 2
  Scopus rating (2014): SJR 1.481 SNIP 2.478 CiteScore 3.28
  BFI (2013): BFI-level 2
  Scopus rating (2013): SJR 1.863 SNIP 3.523 CiteScore 5.05
  ISI indexed (2013): ISI indexed yes
  Web of Science (2013): Indexed yes
  BFI (2012): BFI-level 2
  Scopus rating (2012): SJR 2.174 SNIP 3.985 CiteScore 4.26
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  BFI (2011): BFI-level 2
  Scopus rating (2011): SJR 0.899 SNIP 1.467 CiteScore 2.17
  ISI indexed (2011): ISI indexed no
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Computational aspects of electronic transport in nanoscale devices

This thesis is concerned with the modeling of electronic properties of nano-scale devices. In particular the computational aspects of calculating the transmission and current-voltage characteristics of Landauer-Büttiker two-probe systems are in focus. To begin with, the main existing methods are described in detail and benchmarked. These are the Green’s function method and the wave function matching method. The methods are subsequently combined in a hybrid scheme in order to benefit from a common formalism. The most time demanding stages of common electronic transport calculations are identified. For systems of more than about a hundred atoms, two specific tasks stand out; the evaluation of self-energy matrices to describe the coupling between the electrodes and the device, and the solution of the central region Schrödinger equation either by matrix inverse of by solving a system of linear equations. In this work the objective is to develop new efficient algorithms for these tasks in order to model nano-scale systems of larger size in the future. The starting point of the new methods is the combined formalism of the Green’s function and wave function matching methods. The first new algorithm described is for the calculation of the block tridiagonal matrix inverse of a block tridiagonal matrix in O(N) operations. This algorithm also leads to an optimal evaluation of the frequently used Caroli transmission formula. A modified wave function matching scheme is then developed which allows for a significant reduction in the cost of the self-energy matrix calculations when combined with an iterative eigensolver. Finally, such an iterative eigensolver is developed and implemented based of a shift-and-invert Krylov subspace approach. The method is applied to a selection of nano-scale systems and speed-ups of up to an order of magnitude are achieved.

A study on regularization parameter choice in near-field acoustical holography

Regularization plays an important role in Near-field Acoustical Holography (NAH), and choosing the right amount of regularization is crucial in order to get a meaningful solution. An automated method such as the L-curve or Generalized Cross-Validation (GCV) is often used in NAH to choose a regularization parameter. These parameter choice methods (PCMs) are attractive, since they require no a priori knowledge about the noise. However, there seems to be no clear understanding of when one PCM is better than the other. This paper presents comparisons of three PCMs: GCV, L-curve and Normalized Cumulative Periodogram (NCP). The latter method is new within NAH and it is based on the Fourier transform of the residual vector. The methods are used in connection with three NAH methods: Statistically Optimized Near-field Acoustical Holography (SONAH), the Inverse Boundary Element Method (IBEM), and the Equivalent Source Method (ESM). All combinations of the PCMs and the NAH methods are investigated using simulated measurements with different types of noise added to the input. Finally, the comparisons are carried out for a practical experiment. This aim of this work is to create a better understanding of which mechanisms that affect the performance of the different PCMs.
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BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
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Scopus rating (2016): CiteScore 1.83 SJR 0.749 SNIP 1.27
Web of Science (2016): Indexed yes
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Scopus rating (2015): SJR 0.802 SNIP 1.437 CiteScore 1.77
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 0.788 SNIP 1.423 CiteScore 1.8
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 0.705 SNIP 1.966 CiteScore 2
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.763 SNIP 1.622 CiteScore 1.75
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Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.695 SNIP 1.642 CiteScore 1.68
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 0.754 SNIP 1.528
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 0.783 SNIP 1.717
Web of Science (2009): Indexed yes
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Scopus rating (2008): SJR 0.848 SNIP 1.633
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.865 SNIP 1.647
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.752 SNIP 1.559
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.954 SNIP 1.749
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.77 SNIP 1.787
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.882 SNIP 1.712
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.87 SNIP 1.501
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.719 SNIP 1.467
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.621 SNIP 1.411
Web of Science (2000): Indexed yes
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Block Tridiagonal Matrix Inversion and Fast Transmission Calculations

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Authors: Petersen, D. E. (Ekstern), Sørensen, H. H. B. (Intern), Hansen, P. C. (Intern), Skelboe, S. (Ekstern), Stokbro, K. (Ekstern)
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Scopus rating (2015): SJR 2.098 SNIP 1.988 CiteScore 2.92
Web of Science (2015): Indexed yes
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Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.227 SNIP 2.45 CiteScore 3.3
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.161 SNIP 2.052 CiteScore 2.69
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.06 SNIP 2.194 CiteScore 2.99
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.185 SNIP 2.096
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.439 SNIP 2.219
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 2.247 SNIP 2.03
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.377 SNIP 2.379
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 2.182 SNIP 2.285
Web of Science (2006): Indexed yes
Krylov subspace method for evaluating the self-energy matrices in electron transport calculations

We present a Krylov subspace method for evaluating the self-energy matrices used in the Green’s function formulation of electron transport in nanoscale devices. A procedure based on the Arnoldi method is employed to obtain solutions of the quadratic eigenvalue problem associated with the infinite layered systems of the electrodes. One complex and two real shift-and-invert transformations are adopted to select interior eigenpairs with complex eigenvalues on or in the vicinity of the unit circle that correspond to the propagating and evanescent modes of most influence in electron transport calculations. Numerical tests within a density functional theory framework are provided to validate the accuracy and robustness of the proposed method, which in most cases is an order of magnitude faster than conventional methods.

General information
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Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, University of Copenhagen
Authors: Sørensen, H. H. B. (Intern), Hansen, P. C. (Intern), Petersen, D. E. (Ekstern), Skelboe, S. (Ekstern), Stokbro, K. (Intern)
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Scopus rating (2016): CiteScore 3.16
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.933 SNIP 0.94 CiteScore 2.8
Web of Science (2015): Indexed yes
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Scopus rating (2013): SJR 2.785 SNIP 1.339 CiteScore 3.55
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Noise propagation in regularizing iterations for image deblurring

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Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Department of Management Engineering
Authors: Hansen, P. C. (Intern), Jensen, T. K. (Intern)
Pages: 204-220
Finite Discrete Gabor Analysis

Gabor analysis is a method for analyzing signals through the use of a set of basic building blocks. The building blocks consist of a certain function (the window) that is shifted in time and frequency. The Gabor expansion of a signal contains information on the behavior of the signal in certain frequency bands at certain times. Gabor theory can be formulated for both functions on the real line and for discrete signals of finite length. The two theories are largely the same because many aspects come from the same underlying theory of locally compact Abelian groups. The two types of Gabor systems can also be related by sampling and periodization. This thesis extends on this theory by showing new results for window construction. It also provides a discussion of the problems associated to discrete Gabor bases. The sampling and periodization connection is handy because it allows Gabor systems on the real line to be well approximated by finite and discrete Gabor frames. This method of approximation is especially attractive because efficient numerical methods exists for doing computations with finite, discrete Gabor systems. This thesis presents new algorithms for the efficient computation of finite, discrete Gabor coefficients. Reconstruction of a signal from its Gabor coefficients is done by the use of a so-called dual window. This thesis presents a number of iterative algorithms to compute dual and self-dual windows. The Linear Time Frequency Toolbox is a Matlab/Octave/C toolbox for doing basic discrete time/frequency and Gabor analysis. It is intended to be both an educational and a computational tool. The toolbox was developed as part of this Ph.D. project to provide a solid foundation for the field of computational Gabor analysis.

A convex programming approach to anisotropic smoothing

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Applied functional analysis
Authors: Søndergaard, P. L. (Intern), Hansen, P. C. (Intern), Christensen, O. (Intern)
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Ambiguity in depth resolution in potential field inversion

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Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Università degli Studi di Napoli Federico II
Authors: Fedi, M. (Ekstern), Hansen, P. C. (Intern), Paoletti, V. (Ekstern)
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An adaptive pruning algorithm for the discrete L-curve criterion

We describe a robust and adaptive implementation of the L-curve criterion, i.e., for locating the corner of a discrete L-curve consisting of a log-log plot of corresponding residual and solution norms of regularized solutions from a method with a discrete regularization parameter (such as truncated SVD or regularizing CG iterations). Our algorithm needs no pre-defined parameters, and in order to capture the global features of the curve in an adaptive fashion, we use a sequence of pruned L-curves that correspond to considering the curves at different scales. We compare our new algorithm to existing algorithms and demonstrate its robustness by numerical examples.

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Authors: Hansen, P. C. (Intern), Jensen, T. K. (Intern), Rodriguez, G. (Ekstern)
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BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.082 SNIP 1.625 CiteScore 1.6
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
A projection-based approach to general-form Tikhonov regularization

We present a projection-based iterative algorithm for computing general-form Tikhonov regularized solutions to the problem \( \min_x |Ax-b|^2 + \lambda^2 |Lx|^2 \), where the regularization matrix \( L \) is not the identity. Our algorithm is designed for the common case where \( \lambda \) is not known a priori. It is based on a joint bidiagonalization algorithm and is appropriate for large-scale problems when it is computationally infeasible to transform the regularized problem to standard form. By considering the projected problem, we show how estimates of the corresponding optimal regularization parameter can be efficiently obtained. Numerical results illustrate the promise of our projection-based approach.

General information

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Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Tufts University
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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Iterative Regularization with Minimum-Residual Methods

We study the regularization properties of iterative minimum-residual methods applied to discrete ill-posed problems. In these methods, the projection onto the underlying Krylov subspace acts as a regularizer, and the emphasis of this work is on the role played by the basis vectors of these Krylov subspaces. We provide a combination of theory and numerical examples, and our analysis confirms the experience that MINRES and MR-II can work as general regularization methods. We also demonstrate theoretically and experimentally that the same is not true, in general, for GMRES and RRGMRES their success as regularization methods is highly problem dependent.

General information
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Organisations: Department of Informatics and Mathematical Modeling, Scientific Computing
Authors: Jensen, T. K. (Intern), Hansen, P. C. (Intern)
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Large-scale methods in image deblurring

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Organisations: Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern)
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Host publication information
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Publisher: Springer
Editors: Kågström, B., Elmoth, E., Dongarra, J. J., Wasniewski, J.

Series: Lecture Notes in Computer Science
Number: 4699
Main Research Area: Technical/natural sciences
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Source-ID: 207759
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Regularization Tools Version 4.0 for Matlab 7.3

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Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern)
Pages: 189-194
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Main Research Area: Technical/natural sciences

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Scopus rating (2016): SJR 1.094 SNIP 1.251 CiteScore 1.4
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BFI (2015): BFI-level 2
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BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.218 SNIP 1.556 CiteScore 1.57
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.002 SNIP 1.179 CiteScore 1.22
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.994 SNIP 1.398 CiteScore 1.38
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.765 SNIP 1.213 CiteScore 1.18
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Subspace-Based Noise Reduction for Speech Signals via Diagonal and Triangular Matrix Decompositions: Survey and Analysis

We survey the definitions and use of rank-revealing matrix decompositions in single-channel noise reduction algorithms for speech signals. Our algorithms are based on the rank-reduction paradigm and, in particular, signal subspace techniques. The focus is on practical working algorithms, using both diagonal (eigenvalue and singular value) decompositions and rank-revealing triangular decompositions (ULV, URV, VSV, ULLV and ULLIV). In addition we show how the subspace-based algorithms can be evaluated and compared by means of simple FIR filter interpretations. The algorithms are illustrated with working Matlab code and applications in speech processing.

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Jensen, S. H. (Intern)
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Pages: 092953
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Journal: EURASIP Journal on Applied Signal Processing
Volume: 2007
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Web of Science (2007): Indexed yes
Web of Science (2006): Indexed yes
Web of Science (2005): Indexed yes
Scopus rating (2003): SNIP 0
Scopus rating (2002): SNIP 0.133
Scopus rating (2001): SNIP 0.497
Scopus rating (2000): SNIP 0.143
Scopus rating (1999): SNIP 0.437
Original language: English
DOIs:
Stabilization Algorithms for Large-Scale Problems

The focus of the project is on stabilization of large-scale inverse problems where structured models and iterative algorithms are necessary for computing approximate solutions. For this purpose, we study various iterative Krylov methods and their abilities to produce regularized solutions. Some of the Krylov methods have previously been studied and identified as iterative regularization methods, whereas others have been proposed in the literature, but only sparsely studied in practice. This thesis considerably improves the understanding of these methods. Image deblurring problems constitute a nice class of large-scale problems for which the various methods can be tested. Therefore, this present work includes a separate study of the matrix structures that appear in this connection – not least to create a common basis for discussions. Another important part of the thesis is regularization matrices for the formulation of inverse problems on general form. Special classes of regularization matrices for large-scale problems (among these also two-dimensional problems) have been analyzed. Moreover, the above mentioned Krylov methods have also been analyzed in connection with the solution of problems on general form, and a new extension to the methods has been developed for this purpose. The L-curve method is one among several parameter choice methods that can be used in connection with the solution of inverse problems. A part of the work has resulted in a new heuristic for the localization of the corner of a discrete L-curve. This heuristic is implemented as a part of a larger algorithm which is developed in collaboration with G. Rodríguez and P. C. Hansen. Last, but not least, a large part of the project has, in different ways, revolved around the object-oriented Matlab toolbox MOORe Tools developed by PhD Michael Jacobsen. New implementations have been added, and several bugs and shortcomings have been fixed. The work has resulted in three papers that are all included in an appendix for convenience.
Exploiting residual information in the parameter choice for discrete ill-posed problems
Most algorithms for choosing the regularization parameter in a discrete ill-posed problem are based on the norm of the residual vector. In this work we propose a different approach, where we seek to use all the information available in the residual vector. We present important relations between the residual components and the amount of information that is available in the noisy data, and we show how to use statistical tools and fast Fourier transforms to extract this information efficiently. This approach leads to a computationally inexpensive parameter-choice rule based on the normalized cumulative periodogram, which is particularly suited for large-scale problems.
Iterative regularization with minimum-residual methods

We study the regularization properties of iterative minimum-residual methods applied to discrete ill-posed problems. In these methods, the projection onto the underlying Krylov subspace acts as a regularizer, and the emphasis of this work is on the role played by the basis vectors of these Krylov subspaces. We provide a combination of theory and numerical examples, and our analysis confirms the experience that MINRES and MR-II can work as general regularization methods. We also demonstrate theoretically and experimentally that the same is not true, in general, for GMRES and RRGMRES - their success as regularization methods is highly problem dependent.

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Organisations: Department of Informatics and Mathematical Modeling, Scientific Computing
Authors: Jensen, T. K. (Intern), Hansen, P. C. (Intern)
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Least Squares Solution of Linear Systems

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Nielsen, H. B. (Intern)
Publication date: 2006

Host publication information
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Publisher: Chapman & Hall
Editor: Hogben, L.
ISBN (Print): 1584885106
Main Research Area: Technical/natural sciences
Links:
http://www2.imm.dtu.dk/pubdb/p.php?4347
Source: orbit
Source-ID: 191610
Publication: Research - peer-review › Book chapter – Annual report year: 2006
Smoothing-Norm Preconditioning for Regularizing Minimum-Residual Methods

When GMRES (or a similar minimum-residual algorithm such as RRGMRES, MINRES, or MR-II) is applied to a discrete ill-posed problem with a square matrix, in some cases the iterates can be considered as regularized solutions. We show how to precondition these methods in such a way that the iterations take into account a smoothing norm for the solution. This technique is well established for CGLS, but it does not immediately carry over to minimum-residual methods when the smoothing norm is a seminorm or a Sobolev norm. We develop a new technique which works for any smoothing norm of the form $\|L\|_2 \|x\|_2$ and which preserves symmetry if the coefficient matrix is symmetric. We also discuss the efficient implementation of our preconditioning technique, and we demonstrate its performance with numerical examples in one and two dimensions.

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Authors: Hansen, P. C. (Intern), Jensen, T. K. (Intern)
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Journal: SIAM Journal on Matrix Analysis and Applications
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BFI (2016): BFI-level 2
Scopus rating (2016): SJR 2.074 SNIP 1.899 CiteScore 2.51
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.941 SNIP 1.702 CiteScore 2.22
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.723 SNIP 2.128 CiteScore 2.18
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.577 SNIP 1.716 CiteScore 2.04
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.421 SNIP 1.635 CiteScore 1.79
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.422 SNIP 1.658 CiteScore 1.93
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.097 SNIP 1.487
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.36 SNIP 1.77
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.539 SNIP 2.034
Scopus rating (2007): SJR 1.396 SNIP 1.851
Scopus rating (2006): SJR 1.35 SNIP 2.09
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.703 SNIP 2.206
Scopus rating (2004): SJR 1.249 SNIP 2.059
Scopus rating (2003): SJR 0.984 SNIP 1.51
Scopus rating (2002): SJR 1.308 SNIP 1.51
Scopus rating (2001): SJR 1.301 SNIP 1.469
Web of Science (2001): Indexed yes
Subspace-Based Noise Reduction for Speech Signals via Diagonal and Triangular Matrix Decompositions

We survey the definitions and use of rank-revealing matrix decompositions in single-channel noise reduction algorithms for speech signals. Our algorithms are based on the rank-reduction paradigm and, in particular, signal subspace techniques. The focus is on practical working algorithms, using both diagonal (eigenvalue and singular value) decompositions and rank-revealing triangular decompositions (ULV, URV, VSV, ULLV and ULLIV). In addition we show how the subspace-based algorithms can be evaluated and compared by means of simple FIR filter interpretations. The algorithms are illustrated with working Matlab code and applications in speech processing.

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Jensen, S. H. (Intern)
Publication date: 2006

Publication information
Publisher: Informatics and Mathematical Modelling, Technical University of Denmark, DTU
Original language: English
Main Research Area: Technical/natural sciences
SVD, canonical filters., FIR filter interpretation, rank-revealing decompositions, subspace methods, Rank reduction, GSVD, noise reduction, speech processing
Electronic versions:
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Publication: Research - peer-review › Report – Annual report year: 2006

Minimization of linear functionals defined on solutions of large-scale discrete ill-posed problems

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Linköping University
Authors: Eldén, L. (Ekstern), Hansen, P. C. (Intern), Rojas, M. (Intern)
Pages: 329-340
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Journal: BIT Numerical Mathematics
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http://www2.imm.dtu.dk/pubdb/p.php?2985
Source: orbit
Source-ID: 185597
Publication: Research - peer-review › Journal article – Annual report year: 2005

Prewhitening for Rank-Deficient Noise in Subspace Methods for Noise Reduction

A fundamental issue in connection with subspace methods for noise reduction is that the covariance matrix for the noise is required to have full rank, in order for the prewhitening step to be defined. However, there are important cases where this requirement is not fulfilled, e.g., when the noise has narrow-band characteristics, or in the case of tonal noise. We extend the concept of prewhitening to include the case when the noise covariance matrix is rank deficient, using a weighted pseudoinverse and the quotient SVD, and we show how to formulate a general rank-reduction algorithm that works also for rank deficient noise. We also demonstrate how to formulate this algorithm by means of a quotient ULV decomposition,
which allows for faster computation and updating. Finally we apply our algorithm to a problem involving a speech signal contaminated by narrow-band noise.

General information
State: Published
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Authors: Hansen, P. C. (Intern), Jensen, S. H. (Intern)
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Publication information
Journal: I E E E Transactions on Signal Processing
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ISSN (Print): 1053-587X
Ratings:
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Web of Science (2017): Indexed Yes
Scopus rating (2016): SJR 1.591 SNIP 2.587 CiteScore 5.54
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.756 SNIP 2.783 CiteScore 4.65
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.867 SNIP 2.925 CiteScore 4.72
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.504 SNIP 3.349 CiteScore 5.04
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.404 SNIP 3.552 CiteScore 4.81
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.957 SNIP 3.005 CiteScore 4.06
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.201 SNIP 2.925
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.034 SNIP 2.929
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.912 SNIP 2.751
Scopus rating (2007): SJR 1.939 SNIP 3.031
Scopus rating (2006): SJR 2.033 SNIP 3.36
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.399 SNIP 3.964
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.165 SNIP 3.661
Scopus rating (2003): SJR 1.635 SNIP 2.339
Scopus rating (2002): SJR 1.545 SNIP 1.876
Scopus rating (2001): SJR 1.21 SNIP 1.716
Scopus rating (2000): SJR 1.125 SNIP 2.623
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.564 SNIP 1.521
Original language: English
Electronic versions:
Hansen.pdf
DOIs:
UTV Expansion Pack: Special-Purpose Rank-Revealing Algorithms

This collection of Matlab 7.0 software supplements and complements the package UTV Tools from 1999, and includes implementations of special-purpose rank-revealing algorithms developed since the publication of the original package. We provide algorithms for computing and modifying symmetric rank-revealing VSV decompositions, we expand the algorithms for the ULLV decomposition of a matrix pair to handle interference-type problems with a rank-deficient covariance matrix, and we provide a robust and reliable Lanczos algorithm which - despite its simplicity - is able to capture all the dominant singular values of a sparse or structured matrix. These new algorithms have applications in signal processing, optimization and LSI information retrieval.

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Fierro, R. D. (Ekstern), Hansen, P. C. (Intern)
Pages: 47-66
Publication date: 2005
Main Research Area: Technical/natural sciences

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BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.094 SNIP 1.251 CiteScore 1.4
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.038 SNIP 1.251 CiteScore 1.1
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.218 SNIP 1.556 CiteScore 1.57
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.002 SNIP 1.179 CiteScore 1.22
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.994 SNIP 1.398 CiteScore 1.38
ISI indexed (2012): ISI indexed yes
Boundary Control of Linear Evolution PDEs - Continuous and Discrete

Consider a partial differential equation (PDE) of evolution type, such as the wave equation or the heat equation. Assume now that you can influence the behavior of the solution by setting the boundary conditions as you please. This is boundary control in a broad sense. A substantial amount of literature exists in the area of theoretical results concerning control of partial differential equations. The results have included existence and uniqueness of controls, minimum time requirements, regularity of domains, and many others. Another huge research field is that of control theory for ordinary differential equations. This field has mostly concerned engineers and others with practical applications in mind. This thesis makes an attempt to bridge the two research areas. More specifically, we make finite dimensional approximations to certain evolution PDEs, and analyze how properties of the discrete systems resemble the properties of the continuous system. A common framework in which the continuous systems are formulated will be provided. The treatment includes many types of linear evolution PDEs and boundary conditions. We also consider different types of controllability, such as approximate, null- and exact controllability. We will consider discrete systems with a viewpoint similar to that used for the continuous systems. Most importantly, we study what is required of a discretization scheme in order for computed control functions to converge to the true, continuous, control function. Examples exist for convergent discretization schemes for which divergence of the computed controls occur. We dig deeper for three specific cases: The heat equation, the wave equation, and a linear system of thermoelasticity. Different aspects of the theory are exemplified through these case studies. We finally consider how to efficiently implement computer programs for computing controls in practice.
Modular Regularization Algorithms

The class of linear ill-posed problems is introduced along with a range of standard numerical tools and basic concepts from linear algebra, statistics and optimization. Known algorithms for solving linear inverse ill-posed problems are analyzed to determine how they can be decomposed into independent modules. These modules are then combined to form new regularization algorithms with other properties than those we started out with. Several variations are tested using the Matlab toolbox MOORe Tools created in connection with this thesis. Object oriented programming techniques are explained and used to set up the illposed problems in the toolbox. Hereby, we are able to write regularization algorithms that automatically exploit structure in the ill-posed problem without being rewritten explicitly. We explain how to implement a stopping criteria for a parameter choice method based upon an iterative method. The parameter choice method is also used to demonstrate the implementation of the standard-form transformation. We have implemented a simple preconditioner aimed at the preconditioning of the general-form Tikhonov problem and demonstrate its simplicity and efficiency. The steps taken with MOORe Tools to produce several of the figures are demonstrated in the toolbox tutorial. We have included the article "Subspace Preconditioned LSQR for Ill-Posed Problems" that discusses an algorithm that is not easily implemented with MOORe Tools.

An Adaptive Pruning Algorithm for the Discrete L-Curve Criterion

We describe a robust and adaptive implementation of the L-curve criterion, i.e., for locating the corner of a discrete L-curve consisting of a log-log plot of corresponding residual and solution norms of regularized solutions from a method with a discrete regularization parameter (such as truncated SVD or regularizing CG iterations). Our algorithm needs no pre-defined parameters, and in order to capture the global features of the curve in an adaptive fashion, we use a sequence of pruned L-curves that correspond to considering the curves at different scales. We compare our new algorithm to existing algorithms and demonstrate its robustness by numerical examples.
Oblique projections, pseudoinverses, and standard-form transformations

Standard-form transformation is a technique for transforming a discrete ill-posed problem in general form (with a seminorm as regularizing term) into a standard-form problem. We give a simple geometric explanation why the weighted pseudoinverse is the correct inverse to use in the standard-form transformation. Our presentation is based on oblique projections and oblique pseudoinverses - tools that are often overlooked in numerical analysis.

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State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern)
Publication date: 2004

Prewhitening for Narrow-Band Noise in Subspace Methods for Noise Reduction

A fundamental issue in connection with subspace methods for noise reduction is that the covariance matrix for the noise is required to have full rank, in order for the prewhitening step to be defined. However, there are important cases where this requirement is not fulfilled, typically when the noise has narrow-band characteristics, including the case of tonal noise. We extend the concept of prewhitening to include the case when the noise covariance matrix is rank deficient, using a weighted pseudoinverse and the quotient SVD, and we show how to formulate a general rank-reduction algorithm that works also for rank deficient noise. We also demonstrate how to formulate this algorithm by means of a quotient ULV decomposition, which allows for faster computation and updating. Finally we apply our algorithm to a problem involving a speech signal contaminated by narrow-band noise.

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Jensen, S. H. (Intern)
Publication date: 2004

Smoothing-norm preconditioning for GMRES

When GMRES is applied to a discrete ill-posed problem with a square matrix, then the iterates can be considered as regularized solutions. We show how to precondition GMRES in such a way that the iterations take into account a smoothing norm for the solution. This technique is well established for CGLS, but it does not apply directly to GMRES. We develop a similar technique that works for GMRES, without the need for modifications of the smoothing norm, and which preserves symmetry if the coefficient matrix is symmetric. We also discuss the efficient implementation of our algorithm, and we demonstrate its performance with numerical examples in 1D and 2D.
UTV Expansion Pack - Special-Purpose Rank Revealing Algorithms (version 1.0 for Matlab 6.5)
This collection of Matlab software supplements and complements the package UTV Tools from 1999, and includes implementations of special-purpose rank-revealing algorithms developed since the publication of the original package. We provide algorithms for computing and modifying symmetric rank-revealing VSV decompositions, we expand the algorithms for the ULLV decomposition of a matrix pair to handle interference-type problems with a rank deficient covariance matrix, and we provide a robust and reliable Lanczos algorithm which - despite its simplicity - is able to capture all the dominant singular values of a sparse or structured matrix. These new algorithms have applications in signal processing, optimization and LSI information retrieval.

Minimization of Linear Functionals Defined on Solutions of Large-Scale Discrete Ill-Posed Problems
The minimization of linear functionals defined on the solutions of discrete ill-posed problems arises, e.g., in the computation of confidence intervals for these solutions. In 1990, Elden proposed an algorithm for this minimization problem based on a parametric-programming reformulation involving the solution of a sequence of trust-region problems, and using matrix factorizations. In this paper, we describe MLFIP, a large-scale version of this algorithm where a limited-memory trust-region solver is used on the subproblems. We illustrate the use of our algorithm in connection with an inverse heat conduction problem.
Sound source reconstruction using inverse boundary element calculations
Whereas standard boundary element calculations focus on the forward problem of computing the radiated acoustic field from a vibrating structure, the aim in this work is to reverse the process, i.e., to determine vibration from acoustic field data. This inverse problem is brought on a form suited for solution by means of an inverse boundary element method. Since the numerical treatment of the inverse source reconstruction results in a discrete ill-posed problem, regularization is imposed to avoid unstable solutions dominated by errors. In the present work the emphasis is on Tikhonov regularization and parameter-choice methods not requiring an error-norm estimate for choosing the right amount of regularization. Several parameter-choice strategies have been presented lately, but it still remains to be seen how well these can handle industrial applications with real measurement data. In the present work it is demonstrated that the L-curve criterion is robust with respect to the errors in a real measurement situation. In particular, it is shown that the L-curve criterion is superior to the more conventional generalized cross-validation (GCV) approach for the present tire noise studies.
Subspace preconditioned LSQR for discrete ill-posed problems

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Scientific Computing, Stanford University
Authors: Jacobsen, M. (Intern), Hansen, P. C. (Intern), Saunders, M. A. (Ekstern)
Pages: 975-989
Publication date: 2003
Main Research Area: Technical/natural sciences

Publication information
Journal: BIT Numerical Mathematics
Volume: 43
Issue number: suppl.
Original language: English
Links:
Source: orbit
Source-ID: 58446
Publication: Research - peer-review › Journal article – Annual report year: 2003
Deconvolution and Regularization with Toeplitz Matrices

By deconvolution we mean the solution of a linear first-kind integral equation with a convolution-type kernel, i.e., a kernel that depends only on the difference between the two independent variables. Deconvolution problems are special cases of linear first-kind Fredholm integral equations, whose treatment requires the use of regularization methods. The corresponding computational problem takes the form of structured matrix problem with a Toeplitz or block Toeplitz coefficient matrix. The aim of this paper is to present a tutorial survey of numerical algorithms for the practical treatment of these discretized deconvolution problems, with emphasis on methods that take the special structure of the matrix into account. Wherever possible, analogies to classical DFT-based deconvolution problems are drawn. Among other things, we present direct methods for regularization with Toeplitz matrices, and we show how Toeplitz matrix-vector products are computed by means of FFT, being useful in iterative methods. We also introduce the Kronecker product and show how it is used in the discretization and solution of 2-D deconvolution problems whose variables separate.
Exploiting residual information in the regularization of discrete ill-posed problems

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Kilmer, M. (Ekstern), Kjeldsen, R. H. (Ekstern)
Publication date: 2002
L-Curve Curvature Bounds via Lanczos Bidiagonalization

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Calvetti, D. (Ekstern), Hansen, P. C. (Intern), Reichel, L. (Ekstern)
Pages: 134-149
Publication date: 2002
Main Research Area: Technical/natural sciences

Recent Developments in Rank Revealing and Lanczos Methods for TLS-Related Problems

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State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Fierro, R. D. (Ekstern), Hansen, P. C. (Intern)
Pages: 47-56
Publication date: 2002

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Publisher: Kluwer Academic
Editor: van Huffel, S.
Main Research Area: Technical/natural sciences
Conference: Total Least Squares and Errors-in-Variables Modeling, 01/01/2002
Links:
Publication: Research - peer-review › Article in proceedings – Annual report year: 2002

Subspace preconditioned LSQR for discrete ill-posed problems

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Authors: Jacobsen, M. (Intern), Hansen, P. C. (Intern), Saunders, M. A. (Ekstern)
Publication date: 2002

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Links:
Publication: Research › Report – Annual report year: 2002
Truncated VSV Solutions to Symmetric Rank-Deficient Problems

Symmetric VSV decompositions are new rank-revealing decompositions that exploit and preserve symmetry. Truncated VSV solutions are stabilized solutions computed by neglecting blocks in the VSV decomposition with small norm. We compare the truncated VSV solutions with truncated SVD solutions and give perturbation bounds for the VSV solutions. Numerical examples illustrate our results.

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Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Fierro, R. D. (Ekstern), Hansen, P. C. (Intern)
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Publication date: 2002
Main Research Area: Technical/natural sciences

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Volume: 42
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BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.535 SNIP 1.312 CiteScore 1.41
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.15 SNIP 1.275 CiteScore 1.11
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.044 SNIP 1.208 CiteScore 1.01
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.087 SNIP 1.246 CiteScore 1.2
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.967 SNIP 1.141 CiteScore 0.99
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.683 SNIP 1.171 CiteScore 0.79
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.273 SNIP 1.093
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 0.696 SNIP 0.97
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.805 SNIP 1.273
Scopus rating (2007): SJR 0.99 SNIP 1.081
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.869 SNIP 1.058
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.825 SNIP 0.937
Scopus rating (2004): SJR 0.662 SNIP 0.948
Scopus rating (2003): SJR 0.924 SNIP 1.279
Computing Symmetric Rank-Revealing Decompositions via Triangular Factorization

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Yalamov, P. Y. (Ekstern)
Pages: 443-458
Publication date: 2001
Main Research Area: Technical/natural sciences

Publication information
Journal: SIAM Journal on Matrix Analysis and Applications
Volume: 23
Issue number: 2
ISSN (Print): 0895-4798
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 2.074 SNIP 1.899 CiteScore 2.51
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.941 SNIP 1.702 CiteScore 2.22
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.723 SNIP 2.128 CiteScore 2.18
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.577 SNIP 1.716 CiteScore 2.04
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.421 SNIP 1.635 CiteScore 1.79
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.422 SNIP 1.658 CiteScore 1.93
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.097 SNIP 1.487
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.36 SNIP 1.77
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.539 SNIP 2.034
Scopus rating (2007): SJR 1.396 SNIP 1.851
Scopus rating (2006): SJR 1.35 SNIP 2.09
Web of Science (2006): Indexed yes
L-curve curvature bounds via Lanczos bidiagonalization

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Calvetti, D. (Ekstern), Hansen, P. C. (Intern), Reichel, L. (Ekstern)
Publication date: 2001

Publications information
Original language: English
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 58012
Publication: Research - peer-review › Report – Annual report year: 2001

Rank-Revealing Decompositions of Symmetric Toeplitz Matrices

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Yalamov, P. Y. (Ekstern)
Pages: 163-171
Publication date: 2001

Host publication information
Title of host publication: Structured Matrices in Mathematics, Computer Science, and Engineering II
Publisher: American Mathematical Society
Editor: Olshhevsky, V.
Main Research Area: Technical/natural sciences
Conference: Structured Matrices in Mathematics, Computer Science, and Engineering II, 01/01/2001
Links:
Source: orbit
Source-ID: 57901
Publication: Research - peer-review › Article in proceedings – Annual report year: 2001

Sound source reconstruction using inverse BEM

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Schuhmacher, A. P. (Ekstern), Hansen, P. C. (Intern)
Pages: 2109-2112
Publication date: 2001
Sound source reconstruction using inverse boundary element calculations

Whereas standard boundary element calculations focus on the forward problem of computing the radiated acoustic field from a vibrating structure, the aim of the present work is to reverse the process, i.e., to determine vibration from acoustic field data. This inverse problem is brought on a form suited for solution by means of an inverse boundary element method. Since the numerical treatment of the inverse source reconstruction results in a discrete ill-posed problem, regularisation is imposed to avoid unstable solutions dominated by errors. In the present work the emphasis is on Tikhonov regularisation and parameter-choice methods not requiring an error norm estimate for choosing the right amount of regularisation. We demonstrate that the L-curve criterion is robust with respect to the errors in real measurement situations.

The L-Curve and its Use in the Numerical Treatment of Inverse Problems

Truncated VSV solutions to symmetric rank-deficient problems

Symmetric VSV decompositions are new rank-revealing decompositions that exploit and preserve symmetry. Truncated VSV solutions are stabilized solutions computed by neglecting blocks in the VSV decomposition with small norm. We compare the truncated VSV solutions with truncated SVD solutions and give perturbation bounds for the VSV solutions. Numerical examples illustrate our results.
Canonical filters and rank-reduction algorithms

Methods and Applications of Inversion

Stabilization by Perturbation of a $4n^2$ Toeplitz Solver
The L-curve and its use in the numerical treatment of inverse problems

The L-curve is a log-log plot of the norm of a regularized solution versus the norm of the corresponding residual norm. It is a convenient graphical tool for displaying the trade-off between the size of a regularized solution and its fit to the given data, as the regularization parameter varies. The L-curve thus gives insight into the regularizing properties of the underlying regularization method, and it is an aid in choosing an appropriate regularization parameter for the given data. In this chapter we summarize the main properties of the L-curve, and demonstrate by examples its usefulness and its limitations both as an analysis tool and as a method for choosing the regularization parameter.
The LINPACK benchmark in Co-Array Fortran

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Scientific Computing
Authors: Reid, J. K. (Ekstern), Rasmussen, J. M. (Intern), Hansen, P. C. (Intern)
Publication date: 2000

Host publication information
Title of host publication: Proc. 6th European SGI/Cray MPP Workshop
Editor: Jesson, B. J.
Main Research Area: Technical/natural sciences
Conference: Proc. 6th European SGI/Cray MPP Workshop, 01/01/2000
Source: orbit
Source-ID: 200509
Publication: Research - peer-review › Article in proceedings – Annual report year: 2000

The PP-TSVD Algorithm for Image Reconstruction Problems

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Jacobsen, M. (Intern), Rasmussen, J. M. (Intern), Sørensen, H. (Ekstern)
Pages: 171-186
Publication date: 2000

Host publication information
Title of host publication: Methods and Applications of Inversion
Publisher: Springer
Main Research Area: Technical/natural sciences
Conference: Methods and Applications of Inversion, 01/01/2000
Source: orbit
Source-ID: 176480
Publication: Research - peer-review › Article in proceedings – Annual report year: 2000

Tikhonov Regularization and Total Least Squares
Discretizations of inverse problems lead to systems of linear equations with a highly ill-conditioned coefficient matrix, and in order to compute stable solutions to these systems it is necessary to apply regularization methods. We show how Tikhonov's regularization method, which in its original formulation involves a least squares problem, can be recast in a total least squares formulation suited for problems in which both the coefficient matrix and the right-hand side are known only approximately. We analyze the regularizing properties of this method and demonstrate by a numerical example that, in certain cases with large perturbations, the new method is superior to standard regularization methods.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Golub, G. H. (Ekstern), Hansen, P. C. (Intern), O'Leary, D. P. (Ekstern)
Pages: 185-194
Publication date: 2000
Main Research Area: Technical/natural sciences

Publication information
Journal: SIAM Journal of Matrix Analysis and Applications
Volume: 21
Issue number: 1
Constrained Linear Regularization

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Scientific Computing
Authors: Berglund, E. A. (Intern), Hansen, P. C. (Intern), Jacobsen, B. H. (ed.) (Ekstern)
Pages: 46-53
Publication date: 1999

Host publication information
Title of host publication: Proceedings of the Interdisciplinary Inversion Workshop 6
Publisher: Dept. of Earth Science
Experimental Comparison of Signal Subspace Based Noise Reduction Methods

The signal subspace approach for non-parametric speech enhancement is considered. Several algorithms have been proposed in the literature but only partly analyzed. Here, the different algorithms are compared, and the emphasis is put onto the limiting factors and practical behavior of the estimators. Experimental results show that the signal subspace approach may lead to a significant enhancement of the signal to noise ratio of the output signal.

Regularization Tools Version 3.0 for Matlab 5.2

This communication describes Version 3.0 of Regularization Tools, a Matlab package for analysis and solution of discrete ill-posed problems.
Symmetric Rank-Revealing Decompositions

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, University of Rousse
Authors: Hansen, P. C. (Intern), Yalamov, P. Y. (Ekstern)
Number of pages: 11
Publication date: 1999

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 172456
Publication: Research - peer-review › Journal article – Annual report year: 1999

The L-Curve and Its Use in the Numerical Treatment of Inverse Problems

General information
State: Published
UTV Tools: Matlab Templates for Rank-Revealing UTV Decompositions, version 1.0 for Matlab 5.2

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, California State University
Authors: Fierro, R. D. (Ekstern), Hansen, P. C. (Intern), Hansen, P. S. K. (Intern)
Number of pages: 97
Publication date: 1999

Publication information
Place of publication: Lyngby
Publisher: Informatics and Mathematical Modelling, Technical University of Denmark, DTU
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 172457
Publication: Research - peer-review › Report – Annual report year: 1999

UTV Tools: Matlab Templates for Rank-Revealing UTV Decompositions
We describe a Matlab 5.2 package for computing and modifying certain rank-revealing decompositions that have found widespread use in signal processing and other applications. The package focuses on algorithms for URV and ULV decompositions, collectively known as UTV decompositions. We include algorithms for the ULLV decomposition, which generalizes the ULV decomposition to a pair of matrices. For completeness a few algorithms for computation of the RRQR decomposition are also included. The software in this package can be used as is, or can be considered as templates for specialized implementations on signal processors and similar dedicated hardware platforms.

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, California State University
Authors: Fierro, R. D. (Ekstern), Hansen, P. C. (Intern), Hansen, P. S. K. (Intern)
Pages: 165-194
Publication date: 1999
Main Research Area: Technical/natural sciences

Publication information
Journal: Numerical Algorithms
Volume: 20
Issue number: 2-3
ISSN (Print): 1017-1398
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.094 SNIP 1.251 CiteScore 1.4
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.038 SNIP 1.251 CiteScore 1.1
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.218 SNIP 1.556 CiteScore 1.57
Web of Science (2014): Indexed yes
A Coarse-Grained Parallel QR-Factorization Algorithms for Sparse Least Squares Problems

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Ostromsky, T. (Ekstern), Hansen, P. C. (Intern), Zlatev, Z. (Ekstern)
Pages: 937-964
Publication date: 1998
Main Research Area: Technical/natural sciences

Publication information
Journal: Parallel Computing
Volume: 24
ISSN (Print): 0167-8191
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 0.38 SNIP 1.032 CiteScore 1.68
**FIR Filter Representations of Reduce-Rank Noise Reduction**

**General information**

*State:* Published

*Organisations:* Scientific Computing, Department of Informatics and Mathematical Modeling

*Authors:* Hansen, P. C. (Intern), Jensen, S. H. (Intern)

*Pages:* 1737-1741

*Publication date:* 1998

*Main Research Area:* Technical/natural sciences

**Publication information**

*Journal:* IEEE Transactions on Signal Processing

*Volume:* 46

*ISSN (Print):* 1053-587X

*Ratings:

BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes

BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.591 SNIP 2.587 CiteScore 5.54

BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.756 SNIP 2.783 CiteScore 4.65

Links:

http://www2.imm.dtu.dk/pubdb/p.php?460

Source: orbit

Source-ID: 199749

Publication: Research - peer-review › Journal article – Annual report year: 1998

**FIR Filter Representations of Reduce-Rank Noise Reduction**

**General information**

*State:* Published

*Organisations:* Scientific Computing, Department of Informatics and Mathematical Modeling

*Authors:* Hansen, P. C. (Intern), Jensen, S. H. (Intern)

*Pages:* 1737-1741

*Publication date:* 1998

*Main Research Area:* Technical/natural sciences

**Publication information**

*Journal:* IEEE Transactions on Signal Processing

*Volume:* 46

*ISSN (Print):* 1053-587X

*Ratings:

BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes

BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.591 SNIP 2.587 CiteScore 5.54

BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.756 SNIP 2.783 CiteScore 4.65

Links:

http://www2.imm.dtu.dk/pubdb/p.php?460

Source: orbit

Source-ID: 199749

Publication: Research - peer-review › Journal article – Annual report year: 1998

**FIR Filter Representations of Reduce-Rank Noise Reduction**

**General information**

*State:* Published

*Organisations:* Scientific Computing, Department of Informatics and Mathematical Modeling

*Authors:* Hansen, P. C. (Intern), Jensen, S. H. (Intern)

*Pages:* 1737-1741

*Publication date:* 1998

*Main Research Area:* Technical/natural sciences

**Publication information**

*Journal:* IEEE Transactions on Signal Processing

*Volume:* 46

*ISSN (Print):* 1053-587X

*Ratings:

BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes

BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.591 SNIP 2.587 CiteScore 5.54

BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.756 SNIP 2.783 CiteScore 4.65

Links:

http://www2.imm.dtu.dk/pubdb/p.php?460

Source: orbit

Source-ID: 199749

Publication: Research - peer-review › Journal article – Annual report year: 1998

**FIR Filter Representations of Reduce-Rank Noise Reduction**

**General information**

*State:* Published

*Organisations:* Scientific Computing, Department of Informatics and Mathematical Modeling

*Authors:* Hansen, P. C. (Intern), Jensen, S. H. (Intern)

*Pages:* 1737-1741

*Publication date:* 1998

*Main Research Area:* Technical/natural sciences

**Publication information**

*Journal:* IEEE Transactions on Signal Processing

*Volume:* 46

*ISSN (Print):* 1053-587X

*Ratings:

BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes

BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.591 SNIP 2.587 CiteScore 5.54

BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.756 SNIP 2.783 CiteScore 4.65

Links:

http://www2.imm.dtu.dk/pubdb/p.php?460

Source: orbit

Source-ID: 199749

Publication: Research - peer-review › Journal article – Annual report year: 1998

**FIR Filter Representations of Reduce-Rank Noise Reduction**

**General information**

*State:* Published

*Organisations:* Scientific Computing, Department of Informatics and Mathematical Modeling

*Authors:* Hansen, P. C. (Intern), Jensen, S. H. (Intern)

*Pages:* 1737-1741

*Publication date:* 1998

*Main Research Area:* Technical/natural sciences

**Publication information**

*Journal:* IEEE Transactions on Signal Processing

*Volume:* 46

*ISSN (Print):* 1053-587X

*Ratings:

BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes

BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.591 SNIP 2.587 CiteScore 5.54

BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.756 SNIP 2.783 CiteScore 4.65

Links:

http://www2.imm.dtu.dk/pubdb/p.php?460

Source: orbit

Source-ID: 199749

Publication: Research - peer-review › Journal article – Annual report year: 1998
On Speech Enhancement Algorithms Based on Signal Subspace Methods

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Scientific Computing
Authors: Hansen, P. S. K. (Intern), Hansen, P. C. (Intern), Hansen, S. D. (Intern), Sørensen, J. A. (Intern)
Pages: 221-224
Publication date: 1998

Host publication information
Title of host publication: IEEE Nordic Signal Processing Symposium, NORSIG-98
ISBN (Print): 87-985750-8-2
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 200453
Publication: Research › Article in proceedings – Annual report year: 1998

Rank-Deficient and Discrete Ill-Posed Problems: Numerical Aspects of Linear Inversion
Rank-deficient prewhitening with quotient SVD and ULV decompositions

This paper deals with certain theoretical and numerical aspects of prewhitening, which is a technique frequently used in signal processing when dealing with signals degraded by colored noise. In particular, we demonstrate how to prewhiten a signal contaminated by an interfering noisy signal whose covariance matrix is rank deficient. The formulation of our technique is based on the quotient (or generalized) singular value decomposition, and we also show that a quotient-version of the ULV decomposition can be used to provide an efficient updatable implementation.
Regularizational tools - A MATLAB package for analysis and solution of discrete ill-posed problems: Version 3.0 for MATLAB 5.2

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern)
Number of pages: 109
Publication date: 1998

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 170032
Publication: Research - peer-review › Journal article – Annual report year: 1998

Low-rank revealing UTV decompositions
A UTV decomposition of an m x n matrix is a product of an orthogonal matrix, a middle triangular matrix, and another orthogonal matrix. In this paper we present and analyze algorithms for computing updatable rank-revealing UTV decompositions that are efficient whenever the numerical rank of the matrix is much less than its dimensions.

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Fierro, R. (Ekstern)
Pages: 37-55
Publication date: 1997
Main Research Area: Technical/natural sciences

Publication information
Journal: Numerical Algorithms
Volume: 15
Issue number: 1
ISSN (Print): 1017-1398
Ratings:
BFI (2017): BFI-level 2
Regularization by truncated total least squares

The total least squares (TLS) method is a successful method for noise reduction in linear least squares problems in a number of applications. The TLS method is suited to problems in which both the coefficient matrix and the right-hand side are not precisely known. This paper focuses on the use of TLS for solving problems with very ill-conditioned coefficient matrices whose singular values decay gradually (so-called discrete ill-posed problems), where some regularization is necessary to stabilize the computed solution. We filter the solution by truncating the small singular values of the TLS matrix. We express our results in terms of the singular value decomposition (SVD) of the coefficient matrix rather than the augmented matrix. This leads to insight into the filtering properties of the truncated TLS method as compared to regularized least squares solutions. In addition, we propose and test an iterative algorithm based on Lanczos bidiagonalization for computing truncated TLS solutions. A high-order Godunov-type scheme is developed for the shock interactions in ideal magnetohydrodynamics (MHD). The scheme is based on a nonlinear Riemann solver and follows the basic procedure in the piecewise parabolic method. The scheme takes into account all the discontinuities in ideal MHD and is in a strict conservation form. The scheme is applied to numerical examples, which include shock-tube problems in
ideal MHD and various interactions between strong MHD shocks. All the waves involved in the corresponding Riemann problems are resolved and are correctly displayed in the simulation results. The correctness of the scheme is shown by the comparison between the simulation results and the solutions of the Riemann problems. The robustness of the scheme is demonstrated through the numerical examples. It is shown that the scheme offers the principle advantages of a high-order Godunov-type scheme: robust operation in the presence of very strong waves, thin shock fronts, and thin contact and slip surface discontinuities. An approximate method for solving the Riemann problem is needed to construct Godunov schemes for relativistic hydrodynamical equations. Such an approximate Riemann solver is presented in this paper which treats all waves emanating from an initial discontinuity as themselves discontinuous. Therefore, jump conditions for shocks are approximately used for rarefaction waves. The solver is easy to implement in a Godunov scheme and converges rapidly for relativistic hydrodynamics. The fast convergence of the solver indicates the potential of a higher performance of a Godunov scheme in which the solver is used.
Solving sparse linear least squares problems on some supercomputers by using large dense blocks

Efficient subroutines for dense matrix computations have recently been developed and are available on many high-speed computers. On some computers the speed of many dense matrix operations is near to the peak-performance. For sparse matrices storage and operations can be saved by operating only and storing only nonzero elements. However, the price is a great degradation of the speed of computations on supercomputers (due to the use of indirect addresses, to the need to insert new nonzeros in the sparse storage scheme, to the lack of data locality, etc.). On many high-speed computers a dense matrix technique is preferable to sparse matrix technique when the matrices are not large, because the high computational speed compensates fully the disadvantages of using more arithmetic operations and more storage. For very large matrices the computations must be organized as a sequence of tasks in each of which a dense block is treated. The blocks must be large enough to achieve a high computational speed, but not too large, because this will lead to a large increase in both the computing time and the storage. A special "locally optimized reordering algorithm" (LORA) is described, which reorders the matrix so that dense blocks can be constructed and treated with some standard software, say LAPACK or NAG. These ideas are implemented for linear least-squares problems. The rectangular matrices (that appear in such problems) are decomposed by an orthogonal method. Results obtained on a CRAY C92A computer demonstrate the efficiency of using large dense blocks
Tikhonov regularization and total least squares

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Golub, G. (Ekstern), Hansen, P. C. (Intern), O'Leary, D. P. (Ekstern)
Number of pages: 10
Publication date: 1997

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 168321
ULV-Based Signal Subspace Method for Speech Enhancement

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Scientific Computing
Authors: Hansen, P. S. K. (Intern), Hansen, P. C. (Intern), Hansen, S. D. (Intern), Sørensen, J. A. (Intern)
Pages: 9-12
Publication date: 1997

Host publication information
Title of host publication: International Workshop on Acoustic Echo and Noise Control, IWAENC'97
Place of publication: London
Publisher: Imperial College
Main Research Area: Technical/natural sciences
Conference: International Workshop on Acoustic Echo and Noise Control, 01/01/1997
Source: orbit
Source-ID: 200454
Publication: Research › Article in proceedings – Annual report year: 1997

ULV-based signal subspace methods for speech enhancement

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Hansen, P. (Ekstern), Hansen, S. (Ekstern), Soerensen, J. (Ekstern)
Pages: 9-12
Publication date: 1997

Host publication information
Title of host publication: Proceedings of International Workshop on Acoustic Echo and Noise Control
Publisher: Imperial College London
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 168323
Publication: Research - peer-review › Article in proceedings – Annual report year: 1997

A Parallel sparse QR-factorization algorithm

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), Ostromsky, T. (Ekstern), Zlatev, Z. (Ekstern)
Pages: 462-472
Publication date: 1996

Host publication information
Title of host publication: Applied Parallel Computing, Proceedings
Place of publication: Berlin
Publisher: Springer
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 164792
Publication: Research - peer-review › Article in proceedings – Annual report year: 1996

A Parallel Sparse QR-Factorization Algorithm

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Comparing the performance of SIMD computers by running large air pollution models
To compare the performance and use of three massively parallel SIMD computers, we implemented a large air pollution model on these computers. Using a realistic large-scale model, we gained detailed insight about the performance of the computers involved when used to solve large-scale scientific problems that involve several types of numerical computations. The computers used in our study are the Connection Machines CM-200 and CM-5, and the MasPar MP-2216.

Filter Model of Reduced-Rank Noise Reduction

Noise Reduction of Speech Signals using the Rank-Revealing ULLV Decomposition
Performance of Air Pollution Models on Massively Parallel Computers

To compare the performance and use of three massively parallel SIMD computers, we implemented a large air pollution model on the computers. Using a realistic large-scale model, we gain detailed insight about the performance of the three computers when used to solve large-scale scientific problems that involve several types of numerical computations. The computers considered in our study are the Connection Machines CM-200 and CM-5, and the MasPar MP-2216.
Piecewise polynomial solutions to linear inverse problems
We have presented a new algorithm PP-TSVD that computes piecewise polynomial solutions to ill-posed problems, without a priori knowledge about the positions of the break points. In particular, we can compute piecewise constant functions that describe layered models. Such solutions are useful, e.g., in seismological problems, and the algorithm can also be used as a preprocessor for other methods where break points/discontinuities must be incorporated explicitly.
Regularization algorithms based on total least squares
Discretizations of inverse problems lead to systems of linear equations with a highly ill-conditioned coefficient matrix, and in order to compute stable solutions to these systems it is necessary to apply regularization methods. Classical regularization methods, such as Tikhonov's method or truncated (eem SVD), are not designed for problems in which both the coefficient matrix and the right-hand side are known only approximately. For this reason, we develop (eem TLS)V-based regularization methods that take this situation into account. Here, we survey two different approaches to incorporation of regularization, or stabilization, into the (eem TLS) setting. The two methods are similar in spirit to Tikhonov regularization and truncated (eem SVD), respectively. We analyze the regularizing properties of the methods and demonstrate by numerical examples that in certain cases with large perturbations, these new methods are able to yield more accurate regularized solutions than those produce...

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Hansen, P. C. (Intern), O'Leary, D. P. (Ekstern)
Pages: 127-137
Publication date: 1996

Host publication information
Title of host publication: Recent Advances in Total Least Squares Techniques and Errors-in-Variables
Place of publication: Philadelphia
Publisher: SIAM
Editor: Van Huffel, S.
Main Research Area: Technical/natural sciences
Conference: Recent Advances in Total Least Squares Techniques and Errors-in-Variables Modeling, 01/01/1996
Suppression of reflections by directive probes in spherical near-field measurements

The influence of probe correction in spherical near-field measurements on signals from outside the test volume is investigated theoretically and experimentally. It is found that the suppression of reflections obtained by a directive probe is not disturbed by the probe correction. A geometric relation between the antenna "minimum sphere" and the probe pattern beamwidth is established, whose satisfaction guarantees the absence of numerical instabilities in the far-field computation. The condition is sufficient, but not necessary if the "minimum sphere" of the antenna is in the near field of the probe.
Bibliographical note
Copyright: 1984 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution to servers or lists, or to reuse any copyrighted component of this work in other works must be obtained from the IEEE.

Projects:

Characterization and Reducing the Influence of Model Errors in Inverse Problems
Department of Applied Mathematics and Computer Science
Period: 01/09/2017 → 31/08/2020
Number of participants: 4
Phd Student:
Riis, Nicolai Andre Brogaard (Intern)
Supervisor:
Frikel, Jürgen (Intern)
Hansen, Per Christian (Intern)
Main Supervisor:
Dong, Yiqiu (Intern)

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

Priors for Temporal Tomographic image Reconstruction
Department of Applied Mathematics and Computer Science
Period: 01/04/2015 → 31/03/2018
Number of participants: 3
Phd Student:
Aggrawal, Hari Om (Intern)
Supervisor:
Hansen, Per Christian (Intern)
Main Supervisor:
Andersen, Martin Skovgaard (Intern)
Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

3D Tomography for Material Science
Department of Applied Mathematics and Computer Science
Period: 01/04/2014 → 31/10/2016
Number of participants: 3
Phd Student: Andersen, Michael (Intern)
Supervisor: Hansen, Per Christian (Intern)
Main Supervisor: Dahl, Anders Bjorholm (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Alliance for Imaging and Modelling of Energy Applications
The CINEMA research alliance will develop unique 3D micro-structural characterization methods, which make it possible to investigate components under realistic conditions and in real time. This will enable correlation between performance and local changes in the microstructure.

Department of Energy Conversion and Storage
Imaging and Structural Analysis
Department of Physics
Neutrons and X-rays for Materials Physics
Department of Wind Energy
Composites and Materials Mechanics
Department of Applied Mathematics and Computer Science
Image Analysis & Computer Graphics
Scientific Computing
Mixed Conductors
Statistics and Data Analysis
University of Copenhagen
Northwestern University
University of Manchester
MaxLab
LM Wind Power
Haldor Topsoe AS
Xnovo Technology ApS
Rockwool International A/S
Amminex Emissions Technology A/S
Period: 01/01/2014 → 31/12/2018
Number of participants: 26
Acronym: CINEMA
Project participant:
Mikkelsen, Lars Pilgaard (Intern)
Sørensen, Bent F. (Intern)
Bowen, Jacob R. (Intern)
Kuhn, Luise Theil (Intern)
Larsen, Rasmus (Intern)
Hansen, Per Christian (Intern)
Frandsen, Henrik Lund (Intern)
Gundlach, Carsten (Intern)
Dahl, Anders Bjorholm (Intern)
Yang, Shu-Yi (Intern)
Poulsen, Stefan Othmar (Intern)
Lyckegaard, Allan (Intern)
Lauridsen, Erik Mejdal (Intern)
Sørensen, Henning Osholm (Ekstern)

Project Manager, organisational:
Sørensen, Hanne (Intern)

Phd Student:
Jespersen, Kristine Munk (Intern)
Beil, Johannes (Ekstern)
Andersen, Michael (Intern)
Emerson, Monica Jane (Intern)
De Angelis, Salvatore (Intern)
Birkelund, Klaus (Ekstern)
Jacobsen, Hjalte Sylvest (Intern)
Chapelle, Lucie (Intern)

Supervisor:
Frandsen, Henrik Lund (Intern)

Project Manager, academic:
Andreasen, Jens Wenzel (Intern)

Project Coordinator:
Poulsen, Henning Friis (Intern)

Relations
Activities:
High resolution ptychographic tomography of soft matter
DTU Energy Conversion 2nd International PhD Summer School

Publications:
3D X-Ray Computed Tomography (XCT) of Fatigue Damage Evolution in UD Glass Fibre Composite
Enabling Flexible Polymer Tandem Solar Cells by 3D Ptychographic Imaging
Micromechanical Investigation of Fatigue Damage in Uni-Directional Fibre Composites
Dictionary Based Segmentation in Volumes
Improving organic tandem solar cells based on water-processed nanoparticles by quantitative 3D nanoimaging
Fatigue damage evolution in fibre composites for wind turbine blades
Micromechanical Time-Lapse X-ray CT Study of Fatigue Damage in Uni-Directional Fibre Composites

Project
Large-Scale Algorithms for Nano-Scale atomistic Simulations

Department of Applied Mathematics and Computer Science
Period: 01/01/2014 → 17/03/2014
Number of participants: 4
Phd Student:
Kretschmann, Remo (Ekstern)

Supervisor:
Dammann, Bernd (Intern)
Smidstrup, Søren (Ekstern)
Main Supervisor:
Hansen, Per Christian (Intern)

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

Image Reconstruction under Non-Gaussian Noise
Department of Applied Mathematics and Computer Science
Period: 01/09/2013 → 26/10/2016
Number of participants: 6
PhD Student:
Sciacchitano, Federica (Intern)
Supervisor:
Hansen, Per Christian (Intern)
Main Supervisor:
Dong, Yiqiu (Intern)
Examiner:
Pausen, Rasmus Reinhold (Intern)
Lauze, Francois Bernard (Ekstern)
Steidl, Gabriele (Ekstern)

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

Relations
Publications:
Image reconstruction under non-Gaussian noise
Project: PhD

Statistical Priors in Variational Reconstruction Methods
Department of Applied Mathematics and Computer Science
Period: 01/11/2012 → 24/02/2016
Number of participants: 6
PhD Student:
Romanov, Mikhail (Intern)
Supervisor:
Hansen, Per Christian (Intern)
Main Supervisor:
Dahl, Anders Bjorholm (Intern)
Examiner:
Bærentzen, Jakob Andreas (Intern)
Batenburg, Kees Jost (Ekstern)
Lauze, Francois Bernard (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Anden EU-finansiering
Project: PhD

Training sets in Large-Scale Reconstruction Methods
Department of Applied Mathematics and Computer Science
Period: 01/09/2012 → 23/10/2015
Number of participants: 6
PhD Student:
Large-Scale Computational Electromagnetics for Reflector Antenna Analysis

Department of Applied Mathematics and Computer Science
Period: 15/12/2011 → 19/03/2015
Number of participants: 7
Phd Student: Borries, Oscar Peter (Intern)
Supervisor: Jørgensen, Erik (Intern)
Main Supervisor: Hansen, Per Christian (Intern)
Examiner: Engsig-Karup, Allan Peter (Intern)
Gustafsson, Mats (Ekstern)
Lee, Jin-Fa (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Anden EU-finansiering
Project: PhD

Integrated Modeling of Oil Reservoirs - seismic and geostatistical analysis

Department of Informatics and Mathematical Modeling
Period: 01/03/2010 → 30/08/2013
Number of participants: 6
Phd Student: Lange, Katrine (Intern)
Supervisor: Hansen, Per Christian (Intern)
Stenby, Erling Halfdan (Intern)
Main Supervisor: Mosegaard, Klaus (Intern)
Examiner: Knudsen, Per (Intern)
Kolbjørnsen, Odd (Ekstern)

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

Tomography with Prior Information
Department of Informatics and Mathematical Modeling
Period: 01/10/2009 → 17/06/2013
Number of participants: 7
Phd Student:
Jørgensen, Jakob Sauer (Intern)
Supervisor:
Schmidt, Søren (Intern)
Sidky, Emil (Ekstern)
Main Supervisor:
Hansen, Per Christian (Intern)
Examiner:
Larsen, Rasmus Werner (Intern)
Arridge, Simon R. (Ekstern)
Siltanen, Samuli (Ekstern)

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

Preconditioned Iterative Solvers for Image Reconstructions
Department of Informatics and Mathematical Modeling
Period: 01/03/2008 → 30/11/2008
Number of participants: 2
Phd Student:
Nasar, Noreen (Intern)
Main Supervisor:
Hansen, Per Christian (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Development of tomographic reconstruction methods for material science with focus on advanced scanning methods
Risø National Laboratory for Sustainable Energy
Period: 01/08/2007 → 20/04/2011
Number of participants: 6
Phd Student:
Lyckegaard, Allan (Intern)
Supervisor:
Larsen, Rasmus (Intern)
Main Supervisor:
Lauridsen, Erik Mejdal (Intern)
Examiner:
Hansen, Per Christian (Intern)
Ralph, Brian (Ekstern)
Suter, Robert M. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Grundforskningsfonden
Project: PhD

Modelling of Plasma edge turbulence and transport
Risø National Laboratory for Sustainable Energy
Period: 15/04/2007 → 21/12/2010
Number of participants: 7
Phd Student:
Madsen, Jens (Intern)
Supervisor:
Naulin, Volker (Intern)
Nielsen, Anders Henry (Intern)
Main Supervisor:
Rasmussen, Jens Juul (Intern)
Examiner:
Hansen, Per Christian (Intern)
Heikkinen, Jukka Ahti (Ekstern)
Scott, Bruce D. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsstipendium
Project: PhD

Numerisk approksimation af rand-kontrol problemer
Department of Mathematics
Number of participants: 7
Phd Student:
Mariegaard, Jesper Sandvig (Intern)
Supervisor:
Hansen, Per Christian (Intern)
Pedersen, Michael (Intern)
Main Supervisor:
Knudsen, Kim (Intern)
Examiner:
Sørensen, Mads Peter (Intern)
Hesthaven, Jan (Intern)
Hugger, Jens (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: DTU-lønnet stipendie
Project: PhD
Wavelet Frames in theory and Practice
Department of Mathematics
Period: 01/08/2005 → 05/11/2008
Number of participants: 5
Phd Student:
Lemvig, Jakob (Intern)
Main Supervisor:
Christensen, Ole (Intern)
Examiner:
Hansen, Per Christian (Intern)
Goh, Say Song (Ekstern)
Laugesen, Richard S. (Ekstern)

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

Scientific Computing and Parallel Algorithms in Computational Nano science
Department of Informatics and Mathematical Modeling
Period: 15/04/2005 → 02/07/2008
Number of participants: 7
Phd Student:
Sørensen, Hans Henrik Brandenborg (Intern)
Supervisor:
Skelboe, Stig (Ekstern)
Stokbro, Kurt (Intern)
Main Supervisor:
Hansen, Per Christian (Intern)
Examiner:
Sørensen, Mads Peter (Intern)
Darve, Eric (Ekstern)
Wacker, Andreas (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Brystkrafescreening ved brug af mikrobslker
Department of Electrical Engineering
Period: 01/01/2005 → 24/06/2008
Number of participants: 5
Phd Student:
Rubæk, Tonny (Intern)
Main Supervisor:
Meincke, Peter (Intern)
Examiner:
Hansen, Per Christian (Intern)
Rappaport, Carey M. (Ekstern)
Van den Berg, Peter M. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD
Stabiliserings-Algoritmer til Storskala-Problemer
Department of Informatics and Mathematical Modeling
Period: 01/04/2003 → 31/05/2006
Number of participants: 5
Phd Student:
Jensen, Toke Koldborg (Intern)
Main Supervisor:
Hansen, Per Christian (Intern)
Examiner:
Nielsen, Hans Bruun (Intern)
Fischer, Bernd (Ekstern)
Kilmer, Misha Elena (Ekstern)

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

Diskrete tilnærmelser til kontinuerte frames
Department of Mathematics
Period: 01/09/2002 → 31/05/2007
Number of participants: 6
Phd Student:
Søndergaard, Peter Lempel (Intern)
Supervisor:
Hansen, Per Christian (Intern)
Main Supervisor:
Christensen, Ole (Intern)
Examiner:
Christiansen, Edmund (Ekstern)
25_NN_Studenter/Øvrige medarb. (Ekstern)
Feichtinger, Hans G. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

Tomographic Reconstruction using Anatomical Regularisation
Department of Informatics and Mathematical Modeling
Period: 01/06/2002 → 13/03/2006
Number of participants: 7
Phd Student:
Høgh-Rasmussen, Esben (Intern)
Supervisor:
Hansen, Per Christian (Intern)
Main Supervisor:
Svarer, Claus (Ekstern)
Examiner:
Hansen, Lars Kai (Intern)
Examiner:
Larsen, Jan (Ekstern)
Andersen, Jens Damgaard (Ekstern)
Berry, Michael W. (Ekstern)

Financing sources
Source: Internal funding (public)
**Design af hierarkiske netværk**

Department of Informatics and Mathematical Modeling  
Period: 01/03/2002 → 05/08/2005  
Number of participants: 5  
PhD Student:  
Thomadsen, Tommy (Intern)  
Main Supervisor:  
Clausen, Jens (Intern)  
Examiner:  
Hansen, Per Christian (Intern)  
Boland, Natasha Lesley (Ekstern)  
Zachariasen, Martin (Ekstern)

**Financing sources**  
Source: Internal funding (public)

**PDE-regulering i Scientific Computing**

Department of Informatics and Mathematical Modeling  
Period: 01/02/2001 → 26/11/2004  
Number of participants: 6  
PhD Student:  
Rasmussen, Jan Marthedal (Intern)  
Supervisor:  
Pedersen, Michael (Intern)  
Main Supervisor:  
Hansen, Per Christian (Intern)  
Examiner:  
Bendsøe, Martin P. (Intern)  
Hesthaven, Jan (Intern)  
Hugger, Jens (Ekstern)

**Financing sources**  
Source: Internal funding (public)

**Scientific Computing in Optimization, Simulation and Inversion**  
The goal of this research collaboration is to strengthen our research in scientific computing and algorithm development with emphasis on nonlinear and combinatorial optimization, simulation, and inversion. Among the most promising algorithms today are those based on various splitting techniques for subdivision of the problem as well as the algorithm, and there is a significant overlap between the splitting techniques currently in use within the above areas. In this project we will coordinate the algorithm development within our specific research areas and thus be able to draw collectively upon progress in the individual areas. The focus of our research will lie on the following areas: 1) new splitting techniques for branch-and-bound algorithms in optimization, 2) space-mapping techniques for complex optimization problems, 3) application of domain decomposition and approximation theory in simulation algorithms, 4) preconditioning techniques (based on domain decomposition and multilevel algorithms) for inversion algorithms, 5) methods for including prior knowledge/side constraints in linear and nonlinear inversion algorithms.

**Department of Informatics and Mathematical Modeling**

University of Copenhagen  
Period: 01/12/2000 → 31/12/2002  
Number of participants: 5  
Project participant:  
Hansen, Per Christian (Ekstern)
Modulære regulariserings-algoritmer

Department of Informatics and Mathematical Modeling  
Period: 01/10/2000 → 05/10/2004  
Number of participants: 5  
Phd Student: 
Jacobsen, Michael (Intern)  
Main Supervisor: 
Hansen, Per Christian (Intern)  
Examiner: 
Pedersen, Michael (Intern)  
O’Leary, Dianne Prost (Ekstern)  
Skelboe, Stig (Ekstern)

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

Integral equation techniques for computational electromagnetics

Department of Electrical Engineering  
Period: 01/04/2000 → 06/11/2003  
Number of participants: 6  
Phd Student: 
Jørgensen, Erik (Intern)  
Supervisor: 
Meincke, Peter (Intern)  
Main Supervisor: 
Breinbjerg, Olav (Intern)  
Examiner: 
Hansen, Per Christian (Intern)  
Aksun, M. Irsadi (Ekstern)  
Kolundzija, Branko M. (Ekstern)

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

Ikke-lineær optimering ved anvendelse af surrogatmodeller

Department of Informatics and Mathematical Modeling  
Period: 01/02/2000 → 20/05/2003  
Number of participants: 7  
Phd Student: 
Søndergaard, Jacob (Intern)  
Supervisor: 
Frandsen, Poul Erik (Ekstern)  
Nielsen, Hans Bruun (Intern)  
Main Supervisor: 
Madsen, Kaj (Intern)  
Examiner:
Hansen, Per Christian (Intern)
Ravn, Hans V. (Intern)
Vicente, Luís Nunes (Ekstern)

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

**Multichannel adaptive analysis of rotating systems**
Department of Informatics and Mathematical Modeling
Period: 01/09/1999 → …
Number of participants: 8
Phd Student:
Pedersen, Thorkild Find (Intern)
Supervisor:
Gram-Hansen, Klaus (Ekstern)
Hansen, Per Christian (Intern)
Herlufsen, Henrik (Ekstern)
Main Supervisor:
Hansen, Lars Kai (Intern)
Examiner:
Sørensen, Helge Bjarup Dissing (Intern)
Pedersen, Jacob Mørch (Ekstern)
Randall, R. B. (Ekstern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Erhvervsforskerordningen
Project: PhD

**Signal and Image Processing for Telemedicine (SITE).**
Project No. 3135. The rapid development in sensor technology, signal processing methods and parallel computing technology has enabled the physical realization of complex mathematical models in a diversity of scientific and industrial areas. This beginning interdisciplinary convergence of methodologies in science and technology has already had an impact on several industries and is emerging in medical imaging and more generally in telemedicine. It seems very likely that bringing together specialists from the mentioned areas could further boost the development of medical information processing in Denmark. Such considerations also head to incorporating the disciplines signal processing, scientific computing, and image analysis in the Department of Mathematical Modelling (IMM) together with applied mathematical physics, numerical analysis, operations research, and statistics. Furthermore, there has been established a close cooperation between scientist from DTU and several departments from different hospitals and university clinics.

Department of Informatics and Mathematical Modeling
Period: 01/07/1999 → 30/06/2003
Number of participants: 9
Project participant:
Madsen, Kaj (Intern)
Hansen, Per Christian (Intern)
Hansen, Lars Kai (Intern)
Ersbøll, Bjarne Kjær (Intern)
Carstensen, Jens Michael (Intern)
Larsen, Jan (Intern)
Sørensen, John Aasted (Intern)
Sigurdsson, Sigurdur (Intern)
Project Manager, organisational:
Conradsen, Knut (Intern)

Project
**Storskala inversionsalgoritmer**

Department of Informatics and Mathematical Modeling  
Period: 01/12/1998 → 20/01/2003  
Number of participants: 8  
Phd Student:  
Berglund, Eva Ann-Charlotte (Intern)  
Supervisor:  
Bendtsen, Claus (Intern)  
Jacobsen, Bo Holm (Ekstern)  
Madsen, Kaj (Intern)  
Main Supervisor:  
Hansen, Per Christian (Intern)  
Examiner:  
Nielsen, Hans Bruun (Intern)  
Mosegaard, Klaus (Intern)  
Rojas Larrazabal, Marielba de la Caridad (Intern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Samarbejdsaftalefinans  
Project: PhD

**Investigation of the Effectiveness of Co-Array Fortran**

Department of Informatics and Mathematical Modeling  
Rutherford Appleton Laboratory  
Period: 01/09/1998 → 31/12/2000  
Number of participants: 3  
Project participant:  
Rasmussen, Jan M. (Ekstern)  
Reid, John (Ekstern)  
Project Manager, organisational:  
Hansen, Per Christian (Intern)  

**Multikanal systemer til kombineret adaptiv støjreduktion og signalseperation**

Department of Informatics and Mathematical Modeling  
Period: 01/09/1998 → 14/06/2002  
Number of participants: 8  
Phd Student:  
Kidmose, Preben (Intern)  
Supervisor:  
Hansen, Steffen Duus (Intern)  
Hansen, Per Christian (Intern)  
Sørensen, John Aasted (Intern)  
Main Supervisor:  
Hansen, Lars Kai (Intern)  
Examiner:  
Larsen, Jan (Ekstern)  
Hanssen, Alfred (Ekstern)  
Nolan, John (Ekstern)  

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: DTU-lønnet stipendie  
Project: PhD
**Ph.D. project: Multichannel Systems for Combined Adaptive Noise Reduction and Signal Separation**

The research goal is the development of noise reduction/signal separation methods, based on a combination of spatial localization, subspace filtering and application of model information on the signals being noise reduced or separated. In particular there is aimed for noise reduction, spatial localization and separation of speech signals and a selection of impulse noise and broad band noise sources.

Department of Informatics and Mathematical Modeling  
Period: 01/09/1998 → 31/08/2001  
Number of participants: 5  
Project participant:  
Hansen, Steffen Duus (Intern)  
Hansen, Per Christian (Intern)  
Kidmose, Preben (Intern)  
Project Manager, organisational:  
Sørensen, John Aasted (Intern)  
Kidmose, Preben (Intern)

**Financing sources**  
Source: Unknown  
Name of research programme: Ukendt  
Amount: 1,200,000.00 Danish Kroner

**Parallelle Algoritmer til Lineær Programmering**

Department of Informatics and Mathematical Modeling  
Period: 01/01/1997 → 14/12/2001  
Number of participants: 7  
Phd Student:  
Hultberg, Tim Helge (Intern)  
Supervisor:  
Hansen, Per Christian (Intern)  
Nielsen, Hans Bruun (Intern)  
Main Supervisor:  
Clausen, Jens (Intern)  
Examiner:  
Madsen, Oli B.G. (Intern)  
Drud, Arne (Intern)  
Powell, Susan (Ekstern)

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: DTU-Su Stipendium, Eksperiment

**Research Monograph: Rank-Deficient and Discrete Ill-Posed Problems**

Department of Informatics and Mathematical Modeling  
Period: 01/09/1996 → 01/11/1997  
Number of participants: 1  
Project Manager, organisational:  
Hansen, Per Christian (Intern)

**EPOS: Efficient Parallel algorithms for Optimization and Simulation**

The goal is to develop efficient and reliable parallel algorithms that can utilize supercomputers for solving large-scale optimization and simulation problems.

Department of Informatics and Mathematical Modeling  
Fluid Mechanics
Department of Mechanical Engineering

UNI-C
Period: 03/02/1995 → ...
Number of participants: 10
Project participant:
Clausen, Jens (Intern)
Barker, Vincent A. (Intern)
Hansen, Per Christian (Intern)
Madsen, Oli B.G. (Intern)
Nielsen, Hans Bruun (Intern)
Thomsen, Per Grove (Intern)
Sørensen, Jens Nørkær (Intern)
Wasniewski, Jerzy (Ekstern)
Other:
Caprani, Ole (Ekstern)
Project Manager, organisational:
Madsen, Kaj (Intern)

Financing sources
Source: Unknown
Name of research programme: Ukendt
Amount: 5,758,000.00 Danish Kroner

Algorithms and Software for Rank-Revealing Decompositions
Research co-operation, sponsored by a NATO Collaborative Research Grant.

Department of Informatics and Mathematical Modeling

California State University
Period: 01/01/1995 → 31/12/2000
Number of participants: 2
Project participant:
Fierro, Ricardo D. (Ekstern)
Project Manager, organisational:
Hansen, Per Christian (Intern)

Ph.D. Project: Wavelets in Scientific Computing
This project is concerned with the use of wavelets to solve certain partial differential equations, the nonlinear Schrodinger equation in particular, and the parallel computation of wavelet transforms. The emphasis is on the wavelets with compact support discovered by I. Daubechies.

Department of Informatics and Mathematical Modeling
Period: 01/03/1994 → 28/02/1998
Number of participants: 4
Project participant:
Nielsen, Ole Møller (Intern)
Hansen, Per Christian (Intern)
Sørensen, Mads Peter (Intern)
Project Manager, organisational:
Barker, Vincent A. (Intern)