A Homogeneous and Self-Dual Interior-Point Linear Programming Algorithm for Economic Model Predictive Control

We develop an efficient homogeneous and self-dual interior-point method (IPM) for the linear programs arising in economic model predictive control of constrained linear systems with linear objective functions. The algorithm is based on a Riccati iteration procedure, which is adapted to the linear system of equations solved in homogeneous and self-dual IPMs. Fast convergence is further achieved using a warm-start strategy. We implement the algorithm in MATLAB and C. Its performance is tested using a conceptual power management case study. Closed loop simulations show that 1) the proposed algorithm is significantly faster than several state-of-the-art IPMs based on sparse linear algebra, and 2) warm-start reduces the average number of iterations by 35-40%.

General information
State: Published
Authors: Sokoler, L. E. (Intern), Frison, G. (Intern), Skajaa, A. (Intern), Halvgaard, R. F. (Intern), Jørgensen, J. B. (Intern)
Number of pages: 6
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: IEEE Transactions on Automatic Control
Volume: PP
Issue number: 99
ISSN (Print): 0018-9286
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 4.174 SNIP 3.159 CiteScore 6.06
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 3.926 SNIP 2.884 CiteScore 5.08
Web of Science (2015): Indexed yes
A homogeneous interior-point algorithm for nonsymmetric convex conic optimization

A homogeneous interior-point algorithm for solving nonsymmetric convex conic optimization problems is presented. Starting each iteration from the vicinity of the central path, the method steps in the approximate tangent direction and then applies a correction phase to locate the next well-centered 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. We prove convergence to TeX-accuracy in TeX iterations. To improve performance, the algorithm employs a new Runge–Kutta type second order search direction suitable for the general nonsymmetric conic problem. Moreover, quasi-Newton updating is used to reduce the number of factorizations needed, implemented so that data sparsity can still be exploited. Extensive and promising computational results are presented for the TeX-cone problem, the facility location problem, entropy maximization problems and geometric programs; all formulated as nonsymmetric convex conic optimization problems.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Nanjing University, Stanford University
Authors: Skajaa, A. (Intern), Ye, Y. (Ekstern)
Pages: 391-422
Publication date: 2014
Main Research Area: Technical/natural sciences
A Riccati Based Homogeneous and Self-Dual Interior-Point Method for Linear Economic Model Predictive Control

In this paper, we develop an efficient interior-point method (IPM) for the linear programs arising in economic model predictive control of linear systems. The novelty of our algorithm is that it combines a homogeneous and self-dual model, and a specialized Riccati iteration procedure. We test the algorithm in a conceptual study of power systems management. Simulations show that in comparison to state of the art software implementation of IPMs, our method is significantly faster and scales in a favourable way.
A Warm-Started Homogeneous and Self-Dual Interior-Point Method for Linear Economic Model Predictive Control

In this paper, we present a warm-started homogenous and self-dual interior-point method (IPM) for the linear programs arising in economic model predictive control (MPC) of linear systems. To exploit the structure in the optimization problems, our algorithm utilizes a Riccati iteration procedure which is adapted to the non-standard system solved in homogenous and self-dual IPMs, and specifically tailored to economic MPC. Fast convergence is further achieved by means of a recent warm-starting strategy for homogenous and self-dual IPMs that has not previously been applied to MPC. We implement our algorithm in MATLAB and its performance is analyzed based on a smart grid power management case study. Closed loop simulations show that 1) our algorithm is significantly faster than state-of-the-art IPMs based on sparse linear algebra routines, and 2) warm-starting reduces the number of iterations by approximately 15-35%.

The Homogeneous Interior-Point Algorithm: Nonsymmetric Cones, Warmstarting, and Applications

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:

1. 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.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Center for Energy Resources Engineering
Authors: Skajaa, A. (Intern), Hansen, P. C. (Intern), Jørgensen, J. B. (Intern)
Number of pages: 149
Publication date: 2013

**Publication information**

Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark (DTU)
Original language: English

Series: IMM-PHD-2013
Number: 311
ISSN: 0909-3192
Main Research Area: Technical/natural sciences
Electronic versions: phd311_Skajaa_A.pdf
Publication: Research › Ph.D. thesis – Annual report year: 2014

**Warmstarting the homogeneous and self-dual interior point method for linear and conic quadratic problems**

We present two strategies for warmstarting primal-dual interior point methods for the homogeneous self-dual model when applied to mixed linear and quadratic conic optimization problems. Common to both strategies is their use of only the final (optimal) iterate of the initial problem and their negligible computational cost. This is a major advantage when compared to previously suggested strategies that require a pool of iterates from the solution process of the initial problem. Consequently our strategies are better suited for users who use optimization algorithms as black-box routines which usually only output the final solution. Our two strategies differ in that one assumes knowledge only of the final primal solution while the other assumes the availability of both primal and dual solutions. We analyze the strategies and deduce conditions under which they result in improved theoretical worst-case complexity. We present extensive computational results showing work reductions when warmstarting compared to coldstarting in the range 30–75% depending on the problem class and magnitude of the problem perturbation. The computational experiments thus substantiate that the warmstarting strategies are useful in practice.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Stanford University
Authors: Skajaa, A. (Intern), Andersen, E. D. (Intern), Ye, Y. (Ekstern)
Pages: 1-25
Publication date: 2013
Main Research Area: Technical/natural sciences

**Publication information**

Journal: Mathematical Programming Computation
Volume: 5
Issue number: 1
ISSN (Print): 1867-2949
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 2.451 SNIP 2.995 CiteScore 3.86
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.777 SNIP 3.084 CiteScore 4.68
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.255 SNIP 2.923 CiteScore 3.87
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.946 SNIP 4.042 CiteScore 4.58
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.332 SNIP 4.118 CiteScore 3.94
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.122 SNIP 4.073 CiteScore 1.27
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.721 SNIP 2.903

Original language: English
Warmstart, Interior point method, Homogeneous model, Conic programming

DOI: 10.1007/s12532-012-0046-z
Source: dtu
Source-ID: n::oai:DTIC-ART:springer/380375934::26567
Publication: Research - peer-review › Journal article – Annual report year: 2013

Computational Methods for Model Predictive Control: New Opportunities for Computational Scientists
Power Point presentation.

General information
State: Published
Organisations: Center for Energy Resources Engineering, Department of Informatics and Mathematical Modeling, Scientific Computing, Automation and Control, Computer Science and Engineering, Mathematical Statistics, Technical University of Denmark
Number of pages: 64
Publication date: 2012

Publication information
Original language: English
Publisher: Technical University of Denmark (DTU)
Main Research Area: Technical/natural sciences
Electronic versions:
Computational Methods for Model Predictive Control.pdf
Source: dtu
Source-ID: u::4982
Publication: Research › Sound/Visual production (digital) – Annual report year: 2012

MATLAB syntaksen

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Computer Science and Engineering, Scientific Computing
Authors: Skajaa, A. (Intern), Jørgensen, J. H. (Intern)
Number of pages: 150
Publication date: 2012

Publication information
Publisher: Polyteknisk Boghandel og Forlag
ISBN (Print): 9788750210313
Original language: Danish
Main Research Area: Technical/natural sciences
Real-Time Optimization for Economic Model Predictive Control

In this paper, we develop an efficient homogeneous and self-dual interior-point method for the linear programs arising in economic model predictive control. To exploit structure in the optimization problems, the algorithm employs a highly specialized Riccati iteration procedure. Simulations show that in comparison to conventional interior-point methods, our solver is a) significantly faster per iteration and b) converges in a smaller and less fluctuating number of iterations.

The Matlab Syntax: Explore the syntax

Matlab (MATrix LABoratory) is one of the most widely used programming environments for numerical computations and simulations in the technical sciences. The reason is that Matlab makes it easy to get started as well as to construct advanced programs.

This book is a practical guide to understanding and using Matlab. It works as a quick reference for anyone who is starting to use Matlab for example while enrolled in university studies.

For this reason, the book is limited to covering what is typically used by a university student and is designed as a reference of the syntax including plenty of examples.

While the primary audience of the book is university students, it is well suited for anyone who wants to become acquainted with Matlab.
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.

**General information**
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Center for Energy Resources Engineering
Authors: Skajaa, A. (Intern), Jørgensen, J. B. (Intern), Hansen, P. C. (Intern)
Publication date: 2011

**Publication information**
Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark, DTU Informatics, Building 321
Original language: English
Series: IMM-Technical Report-2011-02
Main Research Area: Technical/natural sciences
Electronic versions:
tr11_02.pdf
Source: orbit
Source-ID: 274427
Publication: Research › Report – Annual report year: 2011

**Find Formlen - Matematik**

**General information**
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling
Authors: Skajaa, A. (Intern), Jørgensen, J. H. (Intern)
Number of pages: 132
Publication date: 2010

**Publication information**
Publisher: Polyteknisk Boghandel og Forlag
Edition: 2
ISBN (Print): 8750210092
Original language: Danish
Main Research Area: Technical/natural sciences
Links:
http://www.polyteknisk.dk/home/Detaljer/9788750210092

**Bibliographical note**
Source: orbit
Source-ID: 279091
Publication: Education › Book – Annual report year: 2011

**Projects:**

**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