

Automatic Differentiation of Optimization Algorithms with Time-Varying Updates

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Abstract

Numerous Optimization Algorithms have a time-varying update rule thanks to, for instance, a changing step size, momentum parameter or, Hessian approximation. In this paper, we apply unrolled or automatic differentiation to a time-varying iterative process and provide convergence (rate) guarantees for the resulting derivative iterates. We adapt these convergence results and apply them to proximal gradient descent with variable step size and FISTA when solving partly smooth problems. We confirm our findings numerically by solving ℓ_1 and ℓ_2 -regularized linear and logistic regression respectively. Our theoretical and numerical results show that the convergence rate of the algorithm is reflected in its derivative iterates.

1 Introduction

For some parameter $\mathbf{u} \in \mathcal{U}$, we consider the following parametric iterative process

$$\mathbf{x}^{(k+1)}(\mathbf{u}) := \mathcal{A}(\mathbf{x}^{(k)}(\mathbf{u}), \mathbf{u}) , \quad (\mathcal{R})$$

for $k \geq 0$, where $\mathbf{x}^{(0)} \in \mathcal{X}$ is the initial iterate and $\mathcal{A}: \mathcal{X} \times \mathcal{U} \rightarrow \mathcal{X}$ is the update mapping. The iterates $\mathbf{x}^{(k)}(\mathbf{u})$ generated by (\mathcal{R}) depend on \mathbf{u} due to the dependence of \mathcal{A} on \mathbf{u} . The goal of performing the iterations (\mathcal{R}) is mainly to solve the non-linear equation

$$\mathbf{x} = \mathcal{A}(\mathbf{x}, \mathbf{u}) , \quad (\mathcal{R}_*)$$

with respect to \mathbf{x} for each parameter \mathbf{u} . A simple example is gradient descent with appropriate step size $\alpha > 0$ where we define $\mathcal{A}(\mathbf{x}, \mathbf{u}) := \mathbf{x} - \alpha \nabla_{\mathbf{x}} F(\mathbf{x}, \mathbf{u})$ for solving a parametric optimization problem of the form

$$\min_{\mathbf{x} \in \mathcal{X}} F(\mathbf{x}, \mathbf{u}) , \quad (\mathcal{P})$$

with a smooth objective $F: \mathcal{X} \times \mathcal{U} \rightarrow \mathbb{R}$. In this case (\mathcal{R}_*) reduces to the optimality condition $\nabla_{\mathbf{x}} F(\mathbf{x}, \mathbf{u}) = 0$.

Automatic Differentiation Of Algorithms

**Andreas Griewank, David Juedes, Jay
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Automatic Differentiation Of Algorithms:

Automatic Differentiation of Algorithms George Corliss,Christele Faure,Andreas Griewank,Laurent Hascoet,Uwe Naumann,2002-01-08 A survey book focusing on the key relationships and synergies between automatic differentiation AD tools and other software tools such as compilers and parallelizers as well as their applications The key objective is to survey the field and present the recent developments In doing so the topics covered shed light on a variety of perspectives They reflect the mathematical aspects such as the differentiation of iterative processes and the analysis of nonsmooth code They cover the scientific programming aspects such as the use of adjoints in optimization and the propagation of rounding errors They also cover implementation problems Automatic Differentiation of Algorithms Andreas Griewank,1991 Mathematics of Computing Numerical Analysis *Evaluating Derivatives* Andreas Griewank,Andrea Walther,2008-11-06 This title is a comprehensive treatment of algorithmic or automatic differentiation The second edition covers recent developments in applications and theory including an elegant NP completeness argument and an introduction to scarcity **Automatic differentiation of algorithms : theory, implementation, and application [proceedings of the First SIAM Workshop on Automatic Differentiation, held in Breckenridge, Colorado, January 6-8, 1991/ edited by Andreas Griewank, George F. Corliss** Andreas Griewank,1991 *Recent Advances in Algorithmic Differentiation* Shaun Forth,Paul Hovland,Eric Phipps,Jean Utke,Andrea Walther,2012-07-30 The proceedings represent the state of knowledge in the area of algorithmic differentiation AD The 31 contributed papers presented at the AD2012 conference cover the application of AD to many areas in science and engineering as well as aspects of AD theory and its implementation in tools For all papers the referees selected from the program committee and the greater community as well as the editors have emphasized accessibility of the presented ideas also to non AD experts In the AD tools arena new implementations are introduced covering for example Java and graphical modeling environments or join the set of existing tools for Fortran New developments in AD algorithms target the efficiency of matrix operation derivatives detection and exploitation of sparsity partial separability the treatment of nonsmooth functions and other high level mathematical aspects of the numerical computations to be differentiated Applications stem from the Earth sciences nuclear engineering fluid dynamics and chemistry to name just a few In many cases the applications in a given area of science or engineering share characteristics that require specific approaches to enable AD capabilities or provide an opportunity for efficiency gains in the derivative computation The description of these characteristics and of the techniques for successfully using AD should make the proceedings a valuable source of information for users of AD tools *ADOL-C* Andreas Griewank,David Juedes,Jay Srinivasan,1991 *Automatic Differentiation* Louis B. Rall,1981 **Principles of Data Assimilation** Seon Ki Park,Milija Zupanski,2022-09-29 Data assimilation is theoretically founded on probability statistics control theory information theory linear algebra and functional analysis At the same time data assimilation is a very practical subject given its goal of

estimating the posterior probability density function in realistic high dimensional applications This puts data assimilation at the intersection between the contrasting requirements of theory and practice Based on over twenty years of teaching courses in data assimilation Principles of Data Assimilation introduces a unique perspective that is firmly based on mathematical theories but also acknowledges practical limitations of the theory With the inclusion of numerous examples and practical case studies throughout this new perspective will help students and researchers to competently interpret data assimilation results and to identify critical challenges of developing data assimilation algorithms The benefit of information theory also introduces new pathways for further development understanding and improvement of data assimilation methods

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Differentiation in Finance Explained Marc Henrard,2017-09-04 This book provides the first practical guide to the function and implementation of algorithmic differentiation in finance Written in a highly accessible way Algorithmic Differentiation Explained will take readers through all the major applications of AD in the derivatives setting with a focus on implementation Algorithmic Differentiation AD has been popular in engineering and computer science in areas such as fluid dynamics and data assimilation for many years Over the last decade it has been increasingly and successfully applied to financial risk management where it provides an efficient way to obtain financial instrument price derivatives with respect to the data inputs Calculating derivatives exposure across a portfolio is no simple task It requires many complex calculations and a large amount of computer power which is prohibitively expensive and can be time consuming Algorithmic differentiation techniques can be very successful in computing Greeks and sensitivities of a portfolio with machine precision Written by a leading practitioner who works and programmes AD it offers a practical analysis of all the major applications of AD in the derivatives setting and guides the reader towards implementation Open source code of the examples is provided with the book with which readers can experiment and perform their own test scenarios without writing the related code themselves

Automatic Differentiation L. B. Rall,2014-01-15 *SIAM Journal on Scientific Computing* ,2001 Applied Parallel and Scientific Computing Pekka Manninen,Per Öster,2013-02-12 This volume constitutes the refereed proceedings of the 11th International Conference on Applied Parallel and Scientific Computing PARA 2012 held in Helsinki Finland in June 2012 The 35 revised full papers presented were selected from numerous submissions and are organized in five technical sessions covering the topics of advances in HPC applications parallel algorithms performance analyses and optimization application of parallel computing in industry and engineering and HPC interval methods In addition three of the topical minisymposia are described by a corresponding overview article on the minisymposia topic In order to cover the state of the art of the field at the end of the book a set of abstracts describe some of the conference talks not elaborated into full articles **Automatic Backward Differentiation for American Monte-Carlo Algorithms - ADD for Conditional Expectations and Indicator Functions** Christian P. Fries,2017 In this note we derive a modified backward automatic differentiation a k a adjoint

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Symbolic Dynamics and Geometry Brian Guenter, Sung-Hee Lee, 2009-12-10 This book explains how to use the symbolic differentiation system D for applications in computer games and engineering simulation The authors describe how to create procedural 3D geometric models link them together to form multibody physical systems and simulate and display their physical behavior in real time The symbolic differentiation capabilities of D can be used in a wide variety of technical applications including computer graphics engineering and mechanical simulation Two Lagrangian physics simulation and procedural 3D geometric modeling are developed in great detail

Handbook of Randomized Computing Sanguthevar Rajasekaran, 2001 **Encyclopedia of Optimization** Christodoulos A. Floudas, Panos M. Pardalos, 2008-09-04 The goal of the Encyclopedia of Optimization is to introduce the reader to a complete set of topics that show the spectrum of research the richness of ideas and the breadth of applications that has come from this field The second edition builds on the success of the former edition with more than 150 completely new entries designed to ensure that the reference addresses recent areas where optimization theories and techniques have advanced Particularly heavy attention resulted in health science and transportation with entries such as Algorithms for Genomics Optimization and Radiotherapy Treatment Design and Crew Scheduling

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Computational Techniques and Applications, CTAC, 1993 **Theorem Proving in Higher Order Logics** Victor A. Carreno, Cesar A. Munoz, Sofiene Tahar, 2003-08-02 This book constitutes the refereed proceedings of the 15th International Conference on Theorem Proving in Higher Order Logics TPHOLs 2002 held in Hampton VA USA in August 2002 The 20 revised full papers presented together with 2 invited contributions were carefully reviewed and selected from 34 submissions All current issues in HOL theorem proving and formal verification of software and hardware systems are addressed Among the HOL theorem proving systems evaluated are Isabelle HOL Isabelle Isar and Coq

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