

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 $\nabla_{\mathbf{x}} F(\mathbf{x}, \mathbf{u}) = 0$.

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Automatic Differentiation of Algorithms George Corliss,Christele Faure,Andreas Griewank,Laurent Hascoet,Uwe Naumann,2013-11-21 Automatic Differentiation AD is a maturing computational technology and has become a mainstream tool used by practicing scientists and computer engineers The rapid advance of hardware computing power and AD tools has enabled practitioners to quickly generate derivative enhanced versions of their code for a broad range of applications in applied research and development Automatic Differentiation of Algorithms provides a comprehensive and authoritative survey of all recent developments new techniques and tools for AD use The book covers all aspects of the subject mathematics scientific programming i e use of adjoints in optimization and implementation i e memory management problems A strong theme of the book is the relationships between AD tools and other software tools such as compilers and parallelizers A rich variety of significant applications are presented as well including optimum shape design problems for which AD offers more efficient tools and techniques 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

Algorithms for Continuous Optimization E. Spedicato,2012-12-06 The NATO Advanced Study Institute on Algorithms for continuous optimization the state of the art was held September 5 18 1993 at II Ciocco Barga Italy It was attended by 75 students among them many well known specialists in optimization from the following countries Belgium Brasil Canada China Czech Republic France Germany Greece Hungary Italy Poland Portugal Rumania Spain Turkey UK USA Venezuela The lectures were given by 17 well known specialists in the field from Brasil China Germany Italy Portugal Russia Sweden UK USA Solving continuous optimization problems is a fundamental task in computational mathematics for applications in areas of engineering economics chemistry biology and so on Most real problems are nonlinear and can be of quite large size Developing efficient algorithms for continuous optimization has been an important field of research in the last 30 years with much additional impetus provided in the last decade by the availability of very fast and parallel computers Techniques like the simplex method that were already considered fully developed thirty years ago have been thoroughly revised and enormously improved The aim of this ASI was to present the state of the art in this field While not all important aspects could be covered in the fifty hours of lectures for instance multiobjective optimization had to be skipped we believe that most important topics were presented many of them by scientists who greatly contributed to their development *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

Principles of Data Assimilation Seon Ki Park,Milija Zupanski,2022-09-29 A unique combination of both theoretical and practical aspects of data assimilation with examples and exercises for students

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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Renate Merker,Wolfgang Schwarz,2013-03-09 Design automation of electronic and hybrid systems is a steadily growing field of interest and a permanent challenge for researchers in Electronics Computer Engineering and Computer Science System Design Automation presents some recent results in design automation of different types of electronic and mechatronic systems It deals with various topics of design automation ranging from high level digital system synthesis through analogue and heterogeneous system analysis and design up to system modeling and simulation Design automation is treated from the aspects of its theoretical fundamentals its basic approach and its methods and tools Several application cases are presented in detail The book consists of three chapters High Level System Synthesis Digital Hardware Software Systems Here embedded systems distributed systems and processor arrays as well as hardware software codesign are treated Also three special application cases are discussed in detail Analog and Heterogeneous System Design System Approach and Methodology This chapter copes with the analysis and design of hybrid systems comprised of analog and digital electronic

and mechanical components System Simulation and Evaluation Methods and Tools In this chapter object oriented Modelling analog system simulation including fault simulation parameter optimization and system validation are regarded The contents of the book are based on material presented at the Workshop System Design Automation SDA 2000 organised by the Sonderforschungsbereich 358 of the Deutsche Forschungsgemeinschaft at TU Dresden

Computational Techniques And Applications - Proceedings Of The Sixth Biennial Conference Henry J Gardner, David Singleton, David Stewart, 1994-06-28 This volume contains papers on computational mathematics development implementation and application of numerical algorithms the development and application of computational systems and numerical modelling Also featured are reports on applications of advanced computer architectures and innovative visualisation techniques It will be a help for developers and implementors of computational methods who wish to find out more about the work of those applying the technology to problems in engineering and science and vice versa

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