

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

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

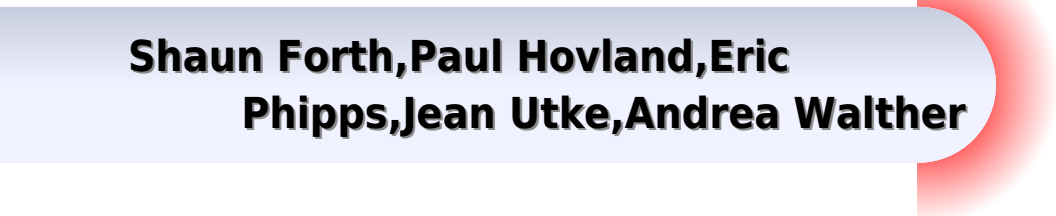
with respect to $\mathbf{x}$ for each parameter $\mathbf{u}$. A simple example is gradient descent with appropriate step size $\alpha > 0$ where we define $\mathcal{A}(\mathbf{x}, \mathbf{u}) := \mathbf{x} - \alpha \nabla_{\mathbf{x}} F(\mathbf{x}, \mathbf{u})$ for solving a parametric optimization problem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

**Shaun Forth,Paul Hovland,Eric
Phipps,Jean Utke,Andrea Walther**



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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

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