

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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