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A Deformation-Adaptive First-Order Optimization Framework Using Jackson q-Gradients

Abdelaziz Chetouani[(1)], Otmane Filali Razzouki[(1)], Anas Charoud[(2)] and Zakaria El Allali[(2)]

[(1)] *ENCG, Mohammed First University, Oujda*
e-mail: otmane.filalirazzouki.d24@ump.ac.ma
e-mail: a.chetouani@ump.ac.ma

[(2)] *FPN, Mohammed First University, Oujda*
e-mail: z.elallali@ump.ma
e-mail: a.charroud@ump.ac.ma

Abstract

Optimization methods form an important part of machine learning algorithms, but they tend to be sensitive to noise in the label data, non-identical data distribution, and the rugged nature of the optimization surface. In this study, we consider the performance of Variable Jackson q-Gradient Descent (VJqGD) optimization method, which utilizes deformations to alter the gradient descent procedure. Specifically, this method involves varying the Jackson deformation parameter through a gradual change from the deformed approach to the normal gradient descent approach.

The developed optimizer is tested on four classification benchmark datasets from UCI Machine Learning Repository, which include Arrhythmia, Fertility, Pima Indians Diabetes, and SPECT Heart. The testing has been performed both in the absence of noise and in the presence of noise where 10% of labels are corrupted. VJqGD is benchmarked with respect to several well-known optimizers like SGD, Adam, RMSprop, AdamW, AdaBelief [1], Lion [3], and Sophia [2].

Based on the experimental findings, it is clear that VJqGD provides competitive or even better predictive capabilities on the majority of data sets and demonstrates stable behavior when used on noisy data. Specifically, the technique demonstrates high or equal highest classification accuracies along with minimal performance deterioration in noisy conditions. Moreover, it was revealed that the deformation parameters have an impact on the optimization process through the sensitivity analysis and were determined for the stability zones that facilitate successful convergence. While the proposed technique comes at the expense of increased computation because of the calculation of the Jackson q-gradient, it may be concluded that deformation-based optimization is a promising technique compared to the standard first-order optimization techniques.

Keywords: Gradient descent, q-calculus, q-derivative, machine learning, adaptive optimization.

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