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From Accelerated First-Order Methods to Structured Nonconvex Optimization

Analysis and Perspectives

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Academic dissertation

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Abstract

Modern technologies like machine learning and data-driven decision systems, depend on solving large and often highly complex optimization problems. These problems rarely come with simple shapes or smooth surfaces; instead, they can twist and bend in ways that make finding good solutions surprisingly difficult. This thesis explores two ideas that help us navigate such complexity more effectively.

The first idea focuses on acceleration and investigates how optimization algorithms can reach good solutions faster while using only basic information such as function values and gradients. By studying these algorithms through a continuous-time analysis, we show that many of the fastest methods behave like carefully designed dynamical systems. This perspective not only clarifies why acceleration happens, but also allows us to design fast algorithms and understand how they behave in the presence of noisy information.

The second idea focuses on a mathematical structural assumption called difference-of-convex (DC) programming, which captures a remarkably wide range of nonconvex problems. By leveraging this structure, we develop practical algorithms that avoid costly operations like projections or high dimensional gradient evaluations, making them efficient for large-scale applications. Through the connection between DC programming and the classical Expectation–Maximization (EM) algorithm, we develop more scalable EM variants and provide the first general performance guarantees for them.

Keywords: accelerated methods, convex optimization, nonconvex optimization, DC programming, EM algorithm, randomized DC algorithm

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