

Preface

In 1984, N. Karmarkar published a seminal paper on algorithmic linear programming. During the subsequent decade, it stimulated a huge outpouring of new algorithmic results by researchers worldwide in many areas of mathematical programming and numerical computation.

This monograph gives an overview of a resulting dramatic reorganization that has occurred in one of these areas: algorithmic differentiable optimization and equation-solving, or, more simply, *algorithmic differentiable programming*. A new portrait of this field has emerged in recent years, which is summarized in the opening chapter and then considered, in more detail, in subsequent chapters.

The primary aim of this monograph is to provide a unified perspective and readable commentary on the above subject, with emphasis being placed on the problems that form its foundation, namely, unconstrained minimization, solving nonlinear equations, the special case of unidimensional programming, and linear programming. The work discussed here derives, in the main, from the author's research in these areas during the post-Karmarkar period, and the focus of attention throughout the monograph will be on the following topics:

- the *formulation of root-level algorithms* with a view to developing an understanding of their interrelationships and underlying mathematical substructure;
- the *illustration of their performance* via basic computational experiments on a mix of contrived and/or realistic test problems;

- a consideration of larger issues that center on the emerging discipline of *algorithmic science*.

For a detailed overview, see Chapter 1 and, in particular, Section 1.3.

The convergence-and-complexity analysis of optimization and equation-solving algorithms considered here is important from a mathematical standpoint. However, this facet of the subject does not lie within our main sphere of interest and it is treated only very briefly. The interested reader can find an in-depth and up-to-date background discussion in several recently published books, for example, Bertsekas [1999], Blum, Cucker, Shub, and Smale [1998], and Kelley [1999]. For additional background perspective on convergence analysis, see also Powell [1991].

The reader is assumed to be familiar with advanced calculus; numerical analysis, in particular, numerical linear algebra; the theory and algorithms of linear and nonlinear programming; and the fundamentals of computer science, in particular, computer programming and the basic models of computation and complexity theory. Thus, this monograph is intended for researchers in optimization and advanced graduate students. But others as well will find the ideas to be of interest.

The book can be used for self-study, as a research seminar text (accompanied by selected readings from the cited literature), or as a supplement to a comprehensive graduate-course textbook on optimization and equation-solving, for example, Bertsekas [1999]. A variety of open avenues of algorithmic research are highlighted in many of the chapters, which can provide the basis for research projects in a seminar or graduate course. And if the typical reader comes away with a refreshing, new perspective on algorithmic differentiable programming and an appreciation of the joys of algorithmic science¹ in general, then my objectives in writing this monograph will more than have been fulfilled.

I feel very fortunate to have been able to participate in the post-Karmarkar algorithmic revolution. It was an extremely interesting and exciting time and afforded the opportunity to interact with many researchers who actively contributed to it. I have also been very fortunate to have known some of the great pioneers in the field of algorithmic differentiable optimization and equation-solving, who discovered its fundamental algorithms and have been a source of inspiration to all that followed them. I thank, in particular, three *algorithmic scientists* par excellence, who exemplify the field: Emeritus Professors George Dantzig (simplex; decomposition), Bill Davidon (variable-metric; collinear-scaling) and Al Goldstein (gradient-projection; cutting-plane).

¹Webster's dictionary defines the word "treatise" (on algorithmic science), which is used in the subtitle of the monograph, as follows: "a systematic exposition or argument in writing, including a methodical discussion of the facts and principles involved and the conclusions reached."

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I'm very grateful to the University Relations Committee of the Boeing Company, Seattle, Washington, and especially to Roger Grimes, for providing seed funding for an algorithmic science feasibility study (1999–2000). Its underlying idea has roots that can be traced all the way back to my graduate studies in the Departments of Computer Science and IE&OR at Berkeley (1968–1973), and I thank my research advisors Professors Beresford Parlett and Stuart Dreyfus for their wise counsel during and after these formative years.

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