

Optimization for Data Analysis

Optimization techniques are at the core of data science, including data analysis and machine learning. An understanding of basic optimization techniques and their fundamental properties provides important grounding for students, researchers, and practitioners in these areas. This text covers the fundamentals of optimization algorithms in a compact, self-contained way, focusing on the techniques most relevant to data science. An introductory chapter demonstrates that many standard problems in data science can be formulated as optimization problems. Next, many fundamental methods in optimization are described and analyzed, including gradient and accelerated gradient methods for unconstrained optimization of smooth (especially convex) functions; the stochastic gradient method, a workhorse algorithm in machine learning; the coordinate descent approach; several key algorithms for constrained optimization problems; algorithms for minimizing nonsmooth functions arising in data science; foundations of the analysis of nonsmooth functions and optimization duality; and the back-propagation approach, relevant to neural networks.

STEPHEN J. WRIGHT holds the George B. Dantzig Professorship, the Sheldon Lubar Chair, and the Amar and Balinder Sohi Professorship of Computer Sciences at the University of Wisconsin–Madison. He is a Discovery Fellow in the Wisconsin Institute for Discovery and works in computational optimization and its applications to data science and many other areas of science and engineering. Wright is also a fellow of the Society for Industrial and Applied Mathematics (SIAM) and recipient of the 2014 W. R. G. Baker Award from IEEE for most outstanding paper, the 2020 Khachiyani Prize by the INFORMS Optimization Society for lifetime achievements in optimization, and the 2020 NeurIPS Test of Time award. He is the author and coauthor of widely used textbooks and reference books in optimization, including *Primal Dual Interior-Point Methods* and *Numerical Optimization*.

BENJAMIN RECHT is Associate Professor in the Department of Electrical Engineering and Computer Sciences at the University of California, Berkeley. His research group studies how to make machine learning systems more robust to interactions with a dynamic and uncertain world by using mathematical tools from optimization, statistics, and dynamical systems. Recht is the recipient of a Presidential Early Career Award for Scientists and Engineers, an Alfred P. Sloan Research Fellowship, the 2012 SIAM/MOS Lagrange Prize in Continuous Optimization, the 2014 Jamon Prize, the 2015 William O. Baker Award for Initiatives in Research, and the 2017 and 2020 NeurIPS Test of Time awards.

Optimization for Data Analysis

STEPHEN J. WRIGHT

University of Wisconsin–Madison

BENJAMIN RECHT

University of California, Berkeley



CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,
New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org

Information on this title: www.cambridge.org/9781316518984

DOI: [10.1017/9781009004282](https://doi.org/10.1017/9781009004282)

© Stephen J. Wright and Benjamin Recht 2022

This publication is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First published 2022

Printed in the United Kingdom by TJ Books Ltd, Padstow Cornwall

A catalogue record for this publication is available from the British Library.

Library of Congress Cataloging-in-Publication Data

Names: Wright, Stephen J., 1960– author. | Recht, Benjamin, author.

Title: Optimization for data analysis / Stephen J. Wright and Benjamin Recht.

Description: New York : Cambridge University Press, [2021] | Includes bibliographical references and index.

Identifiers: LCCN 2021028671 (print) | LCCN 2021028672 (ebook) |

ISBN 9781316518984 (hardback) | ISBN 9781009004282 (epub)

Subjects: LCSH: Big data. | Mathematical optimization. | Quantitative research. | Artificial intelligence. | BISAC: MATHEMATICS / General | MATHEMATICS / General

Classification: LCC QA76.9.B45 W75 2021 (print) | LCC QA76.9.B45 (ebook) | DDC 005.7–dc23

LC record available at <https://lcn.loc.gov/2021028671>

LC ebook record available at <https://lcn.loc.gov/2021028672>

ISBN 978-1-316-51898-4 Hardback

Cambridge University Press has no responsibility for the persistence or accuracy of URLs for external or third-party internet websites referred to in this publication and does not guarantee that any content on such websites is, or will remain, accurate or appropriate.

Cover image courtesy of © Isaac Sparks