

Algorithmic Aspects of Machine Learning

This book bridges theoretical computer science and machine learning by exploring what the two sides can teach each other. It emphasizes the need for flexible, tractable models that better capture not what makes machine learning hard but what makes it easy. Theoretical computer scientists will be introduced to important models in machine learning and to the main questions within the field. Machine learning researchers will be introduced to cutting-edge research in an accessible format and will gain familiarity with a modern algorithmic toolkit, including the method of moments, tensor decompositions, and convex programming relaxations.

The treatment goes beyond worst-case analysis to build a rigorous understanding about the approaches used in practice and to facilitate the discovery of exciting new ways to solve important, long-standing problems.

ANKUR MOITRA is the Rockwell International Associate Professor of Mathematics at the Massachusetts Institute of Technology. He is a principal investigator in the Computer Science and Artificial Intelligence Lab (CSAIL) and a core member of the Theory of Computation Group, Machine Learning@MIT, and the Center for Statistics. The aim of his work is to bridge the gap between theoretical computer science and machine learning by developing algorithms with provable guarantees and foundations for reasoning about their behavior. He is the recipient of a Packard Fellowship, a Sloan Fellowship, a National Science Foundation CAREER Award, an NSF Computing and Innovation Fellowship, and a Hertz Fellowship.

Cambridge University Press
978-1-107-18458-9 — Algorithmic Aspects of Machine Learning
Ankur Moitra
Frontmatter
[More Information](#)

To Diana and Olivia, the sunshine in my life

Algorithmic Aspects of Machine Learning

ANKUR MOITRA
Massachusetts Institute of Technology



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
79 Anson Road, #06–04/06, Singapore 079906

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/9781107184589

DOI: 10.1017/9781316882177

© Ankur Moitra 2018

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 2018

Printed in the United States of America by Sheridan Books, Inc.

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

Library of Congress Cataloging-in-Publication Data

Names: Moitra, Ankur, 1985– author.

Title: Algorithmic aspects of machine learning / Ankur Moitra,
Massachusetts Institute of Technology.

Description: Cambridge, United Kingdom ; New York, NY, USA : Cambridge University Press, 2018. | Includes bibliographical references.

Identifiers: LCCN 2018005020 | ISBN 9781107184589 (hardback) |
ISBN 9781316636008 (paperback)

Subjects: LCSH: Machine learning—Mathematics. | Computer algorithms.

Classification: LCC Q325.5 .M65 2018 | DDC 006.3/1015181—dc23

LC record available at <https://lccn.loc.gov/2018005020>

ISBN 978-1-107-18458-9 Hardback

ISBN 978-1-316-63600-8 Paperback

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.

Contents

<i>Preface</i>	<i>page vii</i>
1 Introduction	1
2 Nonnegative Matrix Factorization	4
2.1 Introduction	4
2.2 Algebraic Algorithms	11
2.3 Stability and Separability	16
2.4 Topic Models	22
2.5 Exercises	27
3 Tensor Decompositions: Algorithms	29
3.1 The Rotation Problem	29
3.2 A Primer on Tensors	31
3.3 Jennrich's Algorithm	35
3.4 Perturbation Bounds	40
3.5 Exercises	46
4 Tensor Decompositions: Applications	48
4.1 Phylogenetic Trees and HMMs	48
4.2 Community Detection	55
4.3 Extensions to Mixed Models	58
4.4 Independent Component Analysis	65
4.5 Exercises	69
5 Sparse Recovery	71
5.1 Introduction	71
5.2 Incoherence and Uncertainty Principles	74
5.3 Pursuit Algorithms	77

5.4	Prony’s Method	80
5.5	Compressed Sensing	83
5.6	Exercises	88
6	Sparse Coding	89
6.1	Introduction	89
6.2	The Undercomplete Case	92
6.3	Gradient Descent	96
6.4	The Overcomplete Case	101
6.5	Exercises	106
7	Gaussian Mixture Models	107
7.1	Introduction	107
7.2	Clustering-Based Algorithms	111
7.3	Discussion of Density Estimation	115
7.4	Clustering-Free Algorithms	118
7.5	A Univariate Algorithm	123
7.6	A View from Algebraic Geometry	127
7.7	Exercises	131
8	Matrix Completion	132
8.1	Introduction	132
8.2	Nuclear Norm	135
8.3	Quantum Golfing	139
	<i>Bibliography</i>	143
	<i>Index</i>	150

Preface

The monograph is based on the class Algorithmic Aspects of Machine Learning taught at MIT in fall 2013, spring 2015, and fall 2017. Thank you to all the students and postdocs who participated in this class and made teaching it a wonderful experience.

Cambridge University Press
978-1-107-18458-9 — Algorithmic Aspects of Machine Learning
Ankur Moitra
Frontmatter
[More Information](#)
