Basic Concepts in Data Structures

Basic Concepts in Data Structures acquaints the reader with the theoretical side of the art of writing computer programs. Instead of concentrating on the technical aspects of how to instruct a computer to perform a certain task, the book switches to the more challenging question of what in fact should be done to solve a given problem.

The volume is the result of several decades of teaching experience in data structures and algorithms. It is self-contained and does not assume any prior knowledge other than of some basic programming and mathematical tools. Klein reproduces his oral teaching style in writing, with one topic leading to another, related one. Most of the classic data structures are covered, though not in a comprehensive manner. Alternatively, some more advanced topics, related to pattern matching and coding, are mentioned.

SHMUEL TOMI KLEIN started teaching in high school, repeating to his classmates almost daily the lectures of their mathematics teacher. As a computer science undergraduate at the Hebrew University of Jerusalem, he acted as teaching assistant in the Statistics Department and has since given courses and lectures on data structures, algorithms, and related topics in English, French, German, and Hebrew.

Klein's research focuses on data compression and text-processing algorithms. He is a full professor and former chair of the Computer Science Department at Bar-Ilan University and a coauthor of more than 100 academic publications and 10 patents.

dedicated to

my spouse Rina

and our children Shoshanit and Itay
Avital and Ariel
Raanan and Yifat
Ayal and Yahav

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CAMBRIDGE
UNIVERSITY PRESS

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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
4843/24, 2nd Floor, Ansari Road, Daryaganj, Delhi 110002, 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/9781107161276
10.1017/9781316676226

First published 2016

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: Klein, Shmuel T., author.
Title: Basic concepts in data structures / Shmuel Tomi Klein, Bar-Ilan University, Israel.
Description: Cambridge, United Kingdom ; New York, NY : Cambridge University Press, [2016] | Includes bibliographical references and index.
Identifiers: LCCN 2016026212 | ISBN 9781107161276 (hardback : alk. paper)
Subjects: LCSH: Data structures (Computer science)
Classification: LCC QA76.9.D35 K558 2016 | DDC 005.7/3–dc23
LC record available at https://lccn.loc.gov/2016026212

ISBN 978-1-107-16127-6 Hardback
ISBN 978-1-316-61384-9 Paperback

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Preface

After having mastered some high-level programming language and acquired knowledge in basic mathematics, it is time for a shift of attention. Instead of concentrating on the technical aspects of *how* to instruct a computer to perform a certain task, we switch to the more challenging question of *what* in fact should be done to solve a given problem. The aim of this book on data structures is to start acquainting the reader with the theoretical side of the art of writing computer programs. This may be considered as a first step in getting familiar with a series of similar fields, such as algorithms, complexity, and computability, that should be learned in parallel to improve practical programming skills.

The book is the result of several decades of teaching experience in data structures and algorithms. In particular, I have taught a course on Data Structures more than 30 times. The book is self-contained and does not assume any prior knowledge of data structures, just a comprehension of basic programming and mathematics tools generally learned at the very beginning of computer science or other related studies. In my university, the course is given in the second semester of the first year of the BSc program, with a prerequisite of Discrete Mathematics and Introduction to Programming, which are first-semester courses. The format is two hours of lecture plus two hours of exercises, led by a teaching assistant, per week.

I have tried to reproduce my oral teaching style in writing. I believe in associative learning, in which one topic leads to another, related one. Although this may divert attention from the central, currently treated subject, it is the cumulative impact of an entire section or chapter that matters. There was no intention to produce a comprehensive compendium of all there is to know about data structures but rather to provide a collection of what many could agree to be its basic ingredients and major building blocks, on which subsequent courses on algorithms could rely. In addition, many more advanced topics are mentioned.

Each chapter comes with its own set of exercises, many of which have appeared in written exams. Solutions to selected exercises appear in the appendix. There are short inserts treating some background concepts: they are slightly indented, set in another font, and separated from the main text by rules. Though each chapter could be understood on its own, even if it has pointers to earlier material, the book has been written with the intent of being read sequentially.

There is of course a long list of people to whom I am indebted for this project, and it is not possible to mention them all. Foremost, I owe all I know to the continuous efforts of my late father to offer me, from childhood on, the best possible education in every domain. This included also private lessons, and I am grateful to my teacher R. Gedalya Stein, who interspersed his Talmud lessons with short flashes to notions of grammar, history, and more, and thereby planted the seeds of the associative learning techniques I adopted later. There is no doubt that my high school mathematics teacher Fernand Biendel was one of the best; he taught us rigor and deep understanding, and the fact that more than half of our class ended up with a PhD in mathematics should be credited to him.

I wish to thank all my teachers at the Hebrew University of Jerusalem and at the Weizmann Institute of Science in Rehovot as well as my colleagues at Bar-Ilan University and elsewhere. Many of them had an impact on my academic career, especially the advisors for my theses, Eli Shamir and Aviezri Fraenkel. Amihood Amir is directly responsible for this book because he asked me, when he was department chair, to teach the course on Data Structures. Thanks also to Franya Franek for providing a contact at Cambridge University Press.

Last, but not least, I wish to thank my spouse and children, to whom this book is dedicated, for their ongoing encouragement and constructive comments during the whole writing period. As to my grandchildren, they have no idea what this is all about, so I thank them for just being there and lighting up my days with their love.