## **Contents**

Pr	Preface				
1	Introduction				
	1.1	Functional vs. Imperative Data Structures	1		
	1.2	Strict vs. Lazy Evaluation	2		
	1.3	Terminology	3		
	1.4	Approach	4		
	1.5	Overview	4		
2	Pers	7			
	2.1	Lists	7		
	2.2	Binary Search Trees	11		
	2.3	Chapter Notes	15		
3	Son	17			
	3.1	Leftist Heaps	17		
	3.2	Binomial Heaps	20		
	3.3	Red-Black Trees	24		
	3.4	Chapter Notes	29		
4	Laz	31			
	4.1	\$-notation	31		
	4.2	Streams	34		
	4.3	Chapter Notes	37		
5	Fundamentals of Amortization				
	5.1	Techniques of Amortized Analysis	39		
	5.2	Queues	42		
	5.3	Binomial Heaps	45		
	5.4	Splay Heaps	46		
	5.5	Pairing Heaps	52		

vi Contents

	5.6	The Bad News				
	5.7	Chapte	er Notes	55		
6	Amo	Amortization and Persistence via Lazy Evaluation				
	6.1	Execu	tion Traces and Logical Time	57		
	6.2	Reconciling Amortization and Persistence		58		
		6.2.1	The Role of Lazy Evaluation	59		
		6.2.2	A Framework for Analyzing Lazy Data Structures	59		
	6.3	The B	anker's Method	61		
		6.3.1	Justifying the Banker's Method	62		
		6.3.2	Example: Queues	64		
		6.3.3	Debit Inheritance	67		
	6.4	The Pl	hysicist's Method	68		
		6.4.1	Example: Binomial Heaps	70		
		6.4.2	Example: Queues	72		
		6.4.3	Example: Bottom-Up Mergesort with Sharing	74		
	6.5	Lazy I	Pairing Heaps	79		
	6.6	Chapte	er Notes	81		
7	Eliminating Amortization					
	7.1	Sched	uling	84		
	7.2	Real-Time Queues				
	7.3	Binomial Heaps				
	7.4	Bottom-Up Mergesort with Sharing				
	7.5	Chapter Notes				
8	Lazy Rebuilding					
	8.1	Batche	ed Rebuilding	99		
	8.2	Globa	l Rebuilding	101		
		8.2.1	Example: Hood-Melville Real-Time Queues	102		
	8.3	Lazy Rebuilding				
	8.4	Doubl	e-Ended Queues	106		
		8.4.1	Output-Restricted Deques	107		
		8.4.2	Banker's Deques	108		
		8.4.3	Real-Time Deques	111		
	8.5	Chapte	er Notes	113		
9	Numerical Representations					
	9.1	.1 Positional Number Systems				
	9.2	Binary	Numbers	116		
		9.2.1	Binary Random-Access Lists	119		
		9.2.2	Zeroless Representations	122		

			Contents	vii		
		9.2.3	Lazy Representations	125		
		9.2.4	Segmented Representations	127		
	9.3					
		9.3.1	Skew Binary Random-Access Lists	132		
		9.3.2	Skew Binomial Heaps	134		
	9.4 Trinary and Quaternary Numbers					
	9.5	140				
10	Data	-Struct	ural Bootstrapping	141		
	10.1	Structu	aral Decomposition	142		
		10.1.1	Non-Uniform Recursion and Standard ML	143		
		10.1.2	Binary Random-Access Lists Revisited	144		
		10.1.3	Bootstrapped Queues	146		
	10.2	Structural Abstraction		151		
		10.2.1	Lists With Efficient Catenation	153		
		10.2.2	Heaps With Efficient Merging	158		
	10.3	163				
		10.3.1	Tries	163		
		10.3.2	Generalized Tries	166		
	10.4	Chapte	er Notes	169		
11	Implicit Recursive Slowdown					
	11.1 Queues and Deques					
	11.2	Catena	ble Double-Ended Queues	175		
	11.3 Chapter Notes					
A	Haskell Source Code					
Bil	Bibliography					
Inc	Index					