

Table of Contents

About the Authors.....	xi
About the Technical Reviewer	xiii
Acknowledgments	xv
Introduction	xvii
Chapter 1: Why Optimize?	1
What Do We Mean by Optimization?	1
Why It Is Difficult: Imperative and Declarative	2
Optimization Goals	5
Optimizing Processes.....	7
Optimizing OLTP and OLAP	8
Database Design and Performance	8
Application Development and Performance	10
Other Stages of the Lifecycle	10
PostgreSQL Specifics.....	11
Summary.....	12
Chapter 2: Theory: Yes, We Need It!.....	13
Query Processing Overview	13
Compilation	13
Optimization and Execution.....	14
Relational, Logical, and Physical Operations.....	15
Relational Operations	15
Logical Operations.....	19

TABLE OF CONTENTS

Queries as Expressions: Thinking in Sets	20
Operations and Algorithms	20
Summary.....	21
Chapter 3: Even More Theory: Algorithms.....	23
Algorithm Cost Models.....	23
Data Access Algorithms	24
Storage Structures	25
Full Scan.....	26
Index-Based Table Access	27
Index-Only Scan	28
Comparing Data Access Algorithms	28
Index Structures.....	31
What Is an Index?.....	31
B-Tree Indexes.....	33
Why Are B-Trees Used So Often?.....	35
Bitmaps	35
Other Kinds of Indexes	36
Combining Relations	37
Nested Loops.....	37
Hash-Based Algorithms	39
Sort-Merge Algorithm.....	41
Comparing Algorithms	42
Summary.....	42
Chapter 4: Understanding Execution Plans	43
Putting Everything Together: How an Optimizer Builds an Execution Plan	43
Reading Execution Plans.....	44
Understanding Execution Plans	49
What Is Going On During Optimization?.....	49
Why Are There So Many Execution Plans to Choose From?	50

TABLE OF CONTENTS

How Are Execution Costs Calculated?	51
How Can the Optimizer Be Led Astray?	54
Summary.....	55
Chapter 5: Short Queries and Indexes	57
Which Queries Are Considered Short?	57
Choosing Selection Criteria.....	59
Index Selectivity	60
Unique Indexes and Constraints	61
Indexes and Non-equal Conditions	65
Indexes and Column Transformations	65
Indexes and the <i>like</i> Operator	70
Using Multiple Indexes.....	72
Compound Indexes.....	73
How Do Compound Indexes Work?	74
Lower Selectivity	76
Using Indexes for Data Retrieval	76
Covering Indexes	77
Excessive Selection Criteria.....	79
Partial Indexes	83
Indexes and Join Order	85
When Are Indexes Not Used	88
Avoiding Index Usage	89
Why Does PostgreSQL Ignore My Index?.....	89
Let PostgreSQL Do Its Job!	92
How to Build the Right Index(es)?	97
To Build or Not to Build	97
Which Indexes Are Needed?	98
Which Indexes Are Not Needed?	98
Indexes and Short Query Scalability	99
Summary.....	100

TABLE OF CONTENTS

Chapter 6: Long Queries and Full Scans	101
Which Queries Are Considered Long?	101
Long Queries and Full Scans.....	103
Long Queries and Hash Joins.....	104
Long Queries and the Order of Joins.....	105
What Is a Semi-join?	105
Semi-joins and Join Order.....	107
More on Join Order.....	109
What Is an Anti-join?	112
Semi- and Anti-joins Using the JOIN Operator	113
When Is It Necessary to Specify Join Order?.....	116
Grouping: Filter First, Group Last	118
Grouping: Group First, Select Last.....	125
Using SET operations	128
Avoiding Multiple Scans.....	132
Conclusion	138
Chapter 7: Long Queries: Additional Techniques	139
Structuring Queries.....	139
Temporary Tables and CTEs	140
Temporary Tables	140
Common Table Expressions (CTEs).....	142
Views: To Use or Not to Use.....	147
Why Use Views?	154
Materialized Views	154
Creating and Using Materialized Views	154
Refreshing Materialized Views	156
Create a Materialized View or Not?	156
Do Materialized Views Need to Be Optimized?.....	158
Dependencies	159
Partitioning.....	160

TABLE OF CONTENTS

Parallelism	165
Summary.....	166
Chapter 8: Optimizing Data Modification.....	167
What Is DML?	167
Two Ways to Optimize Data Modification	167
How Does DML Work?.....	168
Low-Level Input/Output.....	168
The Impact of Concurrency Control	169
Data Modification and Indexes.....	172
Mass Updates and Frequent Updates	173
Referential Integrity and Triggers.....	174
Summary.....	175
Chapter 9: Design Matters.....	177
Design Matters.....	177
Why Use a Relational Model?.....	181
Types of Databases.....	182
Entity-Attribute-Value Model	182
Key-Value Model.....	183
Hierarchical Model.....	184
Combining the Best of Different Worlds	185
Flexibility vs. Efficiency and Correctness.....	185
Must We Normalize?	187
Use and Misuse of Surrogate Keys	189
Summary.....	195
Chapter 10: Application Development and Performance.....	197
Response Time Matters	197
World Wide Wait	198
Performance Metrics	199
Impedance Mismatch.....	200

TABLE OF CONTENTS

The Road Paved with Good Intentions	200
Application Development Patterns	201
“Shopping List Problem”	203
Interfaces	205
Welcome to the World of ORM	205
In Search of a Better Solution	207
Summary.....	210
Chapter 11: Functions	211
Function Creation.....	211
Internal Functions.....	212
User-Defined Functions	212
Introducing Procedural Language	213
Dollar Quoting.....	214
Function Parameters and Function Output: Void Functions.....	215
Function Overloading.....	216
Function Execution.....	218
Function Execution Internals.....	220
Functions and Performance.....	223
How Using Functions Can Worsen Performance	224
Any Chance Functions Can Improve Performance?.....	226
Functions and User-Defined Types.....	226
User-Defined Data Types	226
Functions Returning Composite Types	227
Using Composite Types with Nested Structure	231
Functions and Type Dependencies.....	235
Data Manipulation with Functions	236
Functions and Security	238
What About Business Logic?.....	239
Functions in OLAP Systems	240

TABLE OF CONTENTS

Parameterizing	240
No Explicit Dependency on Tables and Views.....	241
Ability to Execute Dynamic SQL.....	241
Stored Procedures	241
Functions with No Results.....	241
Functions and Stored Procedures	242
Transaction Management.....	242
Exception Processing	243
Summary.....	244
Chapter 12: Dynamic SQL.....	245
What Is Dynamic SQL.....	245
Why It Works Better in Postgres	245
What About SQL Injection?	246
How to Use Dynamic SQL in OLTP Systems	246
How to Use Dynamic SQL in OLAP Systems.....	252
Using Dynamic SQL for Flexibility	256
Using Dynamic SQL to Aid the Optimizer	263
FDWs and Dynamic SQL.....	266
Summary.....	267
Chapter 13: Avoiding the Pitfalls of Object-Relational Mapping	269
Why Application Developers Like NORM	269
ORM vs. NORM.....	270
NORM Explained	272
Implementation Details	278
Complex Searches	283
Updates	286
Insert	287
Update	288
Delete	290

TABLE OF CONTENTS

Why Not Store JSON?!	291
Performance Gains.....	291
Working Together with Application Developers.....	292
Summary.....	292
Chapter 14: More Complex Filtering and Search	293
Full Text Search.....	293
Multidimensional and Spatial Search	295
Generalized Index Types in PostgreSQL	295
GIST Indexes.....	296
Indexes for Full Text Search.....	296
Indexing Very Large Tables	297
Indexing JSON and JSONB.....	298
Summary.....	302
Chapter 15: Ultimate Optimization Algorithm.....	303
Major Steps.....	303
Step-by-Step Guide.....	304
Step 1: Short or Long?.....	304
Step 2: Short.....	304
Step 3: Long.....	306
Step 4: Incremental Updates	306
Step 5: Non-incremental Long Query	306
But Wait, There Is More!.....	307
Summary.....	308
Chapter 16: Conclusion.....	309
Index.....	311