Table of Contents

Pre	eface	. xi
1	Grant Thinking	1
1.	Graph Thinking	
	Why Now? Putting Database Technologies in Context	2
	1960s–1980s: Hierarchical Data	3
	1980s–2000s: Entity-Relationship	4
	2000s-2020s: NoSQL	5
	2020s-?: Graph	7
	What Is Graph Thinking?	9
	Complex Problems and Complex Systems	10
	Complex Problems in Business	10
	Making Technology Decisions to Solve Complex Problems	12
	So You Have Graph Data. What's Next?	15
	Seeing the Bigger Picture	19
	Getting Started on Your Journey with Graph Thinking	20
2.	Evolving from Relational to Graph Thinking	21
	Chapter Preview: Translating Relational Concepts to Graph Terminology	21
	Relational Versus Graph: What's the Difference?	22
	Data for Our Running Example	23
	Relational Data Modeling	25
	Entities and Attributes to accomplished in abacomodicies and paradoxis	26
	Building Up to an ERD	27
	Concepts in Graph Data	28
	Fundamental Elements of a Graph	28
	Adjacency	29
	Neighborhoods	30
	Distance La lohold skyar O managolaya C hu F 10 O	30

	Degree		31
	The Graph Schema Language		33
	Vertex Labels and Edge Labels		33
	Properties		34
	Edge Direction		35
	Self-Referencing Edge Labels		38
	Multiplicity of Your Graph		38
	Full Example Graph Model		41
	Relational Versus Graph: Decisions to Consider		43
	Data Modeling		43
	Understanding Graph Data		43
	Mixing Database Design with Application Purpose		44
	Summary		44
3.	Getting Started: A Simple Customer 360		47
	Chapter Preview: Relational Versus Graph		48
	The Foundational Use Case for Graph Data: C360		48
	Why Do Businesses Care About C360?	Viry Now? Putting	50
	Implementing a C360 Application in a Relational System		51
	Data Models		51
	Relational Implementation		54
	Example C360 Queries		58
	Implementing a C360 Application in a Graph System		61
	Data Models		62
	Graph Implementation		63
	Example C360 Queries		70
	Relational Versus Graph: How to Choose?		75
	Relational Versus Graph: Data Modeling		75
	Relational Versus Graph: Representing Relationships		76
	Relational Versus Graph: Query Languages		76
	Relational Versus Graph: Main Points		77
	Summary		78
	,		79
	Making a Technology Choice for Your C360 Application		79
ď.			
4.	Exploring Neighborhoods in Development		
	Chapter Preview: Building a More Realistic Customer 360		81
	1		82
	Should This Be a Vertex or an Edge?		83
	Lost Yet? Let Us Walk You Through Direction		86
	A Graph Has No Name: Common Mistakes in Naming		89
	Our Full Development Graph Model		91

	Before We Start Building	93
	Our Thoughts on the Importance of Data, Queries, and the End User	94
	Implementation Details for Exploring Neighborhoods in Development	95
	Generating More Data for Our Expanded Example	97
	Basic Gremlin Navigation	97
	Advanced Gremlin: Shaping Your Query Results	106
	Shaping Query Results with the project(), fold(), and unfold() Steps	107
	Removing Data from the Results with the where(neq()) Pattern	110
	Planning for Robust Result Payloads with the coalesce() Step	112
	Moving from Development into Production	115
5.	Exploring Neighborhoods in Production	117
	Chapter Preview: Understanding Distributed Graph Data in Apache	
	Cassandra and Securities and Securit	119
	Working with Graph Data in Apache Cassandra	120
	The Most Important Topic to Understand About Data Modeling: Primary	
	Keys	120
	Partition Keys and Data Locality in a Distributed Environment	121
	Understanding Edges, Part 1: Edges in Adjacency Lists	126
	Understanding Edges, Part 2: Clustering Columns	128
	Understanding Edges, Part 3: Materialized Views for Traversals	132
	Graph Data Modeling 201	136
	Finding Indexes with an Intelligent Index Recommendation System	140
	Production Implementation Details and and and bound A 150 at a Company	142
	Materialized Views and Adding Time onto Edges	142
	Our Final C360 Production Schema	144
	Bulk Loading Graph Data	146
	Updating Our Gremlin Queries to Use Time on Edges	149
	Moving On to More Complex, Distributed Graph Problems	152
	Our First 10 Tips to Get from Development to Production	152
6.	Using Trees in Development	155
	Chapter Preview: Navigating Trees, Hierarchical Data, and Cycles	155
	Seeing Hierarchies and Nested Data: Three Examples	156
	Hierarchical Data in a Bill of Materials	156
	Hierarchical Data in Version Control Systems	157
	Hierarchical Data in Self-Organizing Networks	157
	Why Graph Technology for Hierarchical Data?	158
	Finding Your Way Through a Forest of Terminology	159
	Trees, Roots, and Leaves adaptive end I want work ymaling	159
	Depth in Walks, Paths, and Cycles	160
	Understanding Hierarchies with Our Sensor Data	162

	Understand the Data	163
	Conceptual Model Using the GSL Notation	170
	Implement Schema	171
	Before We Build Our Queries	174
	Querying from Leaves to Roots in Development	174
	Where Has This Sensor Sent Information To?	175
	From This Sensor, What Was Its Path to Any Tower?	178
	From Bottom Up to Top Down	184
	Querying from Roots to Leaves in Development	184
	Setup Query: Which Tower Has the Most Sensor Connections So That We	
	Could Explore It for Our Example?	185
	Which Sensors Have Connected Directly to Georgetown?	186
	Find All Sensors That Connected to Georgetown	187
	Depth Limiting in Recursion	189
	Going Back in Time	190
7.	Using Trees in Production	191
	Chapter Preview: Understanding Branching Factor, Depth, and Time on	
	Edges The analysis of the Edges	191
	Understanding Time in the Sensor Data	192
	Final Thoughts on Time Series Data in Graphs	200
	Understanding Branching Factor in Our Example	200
	What Is Branching Factor?	201
	How Do We Get Around Branching Factor?	202
	Production Schema for Our Sensor Data	203
	Querying from Leaves to Roots in Production	205
	Where Has This Sensor Sent Information to, and at What Time?	205
	From This Sensor, Find All Trees up to a Tower by Time	206
	From This Sensor, Find a Valid Tree	209
	Advanced Gremlin: Understanding the where().by() Pattern	211
	Querying from Roots to Leaves in Production	213
	Which Sensors Have Connected to Georgetown Directly, by Time?	214
	What Valid Paths Can We Find from Georgetown Down to All Sensors?	215
	Applying Your Queries to Tower Failure Scenarios	218
	Applying the Final Results of Our Complex Problem	223
	Seeing the Forest for the Trees	223
8.		225
	Chapter Preview: Quantifying Trust in Networks	226
	Thinking About Trust: Three Examples	226
	How Much Do You Trust That Open Invitation?	226
	How Defensible Is an Investigator's Story?	227

	How Do Companies Model Package Delivery?	228
	Fundamental Concepts About Paths	229
	Shortest Paths	230
	Depth-First Search and Breadth-First Search	232
	Learning to See Application Features as Different Path Problems	233
	Finding Paths in a Trust Network	234
	Source Data	234
	A Brief Primer on Bitcoin Terminology	236
	Creating Our Development Schema	236
	Loading Data	237
	Exploring Communities of Trust and I should add to be should be a second and the	238
	Understanding Traversals with Our Bitcoin Trust Network	240
	Which Addresses Are in the First Neighborhood?	240
	Which Addresses Are in the Second Neighborhood?	241
	Which Addresses Are in the Second Neighborhood, but Not the First?	242
	Evaluation Strategies with the Gremlin Query Language	244
	Pick a Random Address to Use for Our Example	245
	Shortest Path Queries	246
	Finding Paths of a Fixed Length	247
	Finding Paths of Any Length	250
	Augmenting Our Paths with the Trust Scores	253
	Do You Trust This Person?	259
82	ong the Complex Problem	
9.	Finding Paths in Production	
	Chapter Preview: Understanding Weights, Distance, and Pruning	
	Weighted Paths and Search Algorithms	262
	Shortest Weighted Path Problem Definition	263
	Shortest Weighted Path Search Optimizations	
	Normalization of Edge Weights for Shortest Path Problems	
	Normalizing the Edge Weights	267
	Updating Our Graph	
	Exploring the Normalized Edge Weights and Described Annual Landson Barrell Lan	
	Some Thoughts Before Moving On to Shortest Weighted Path Queries	
	Shortest Weighted Path Queries and analysis of the surface of the short of the shor	
	Building a Shortest Weighted Path Query for Production	278
	Weighted Paths and Trust in Production Mollowsky Memorial Commence of the Comm	
10.	Recommendations in Development	
	Chapter Preview: Collaborative Filtering for Movie Recommendations	
	Recommendation System Examples	
	How We Give Recommendations in Healthcare	292
	How We Experience Recommendations in Social Media	293

How We Use Deeply Connected Data for Recommendations in Ecommerce	294
An Introduction to Collaborative Filtering	295
Understanding the Problem and Domain	295
Collaborative Filtering with Graph Data	297
Recommendations via Item-Based Collaborative Filtering with Graph Data	298
Three Different Models for Ranking Recommendations	299
Movie Data: Schema, Loading, and Query Review	303
Data Model for Movie Recommendations	303
Schema Code for Movie Recommendations	305
Loading the Movie Data	307
Neighborhood Queries in the Movie Data	311
Tree Queries in the Movie Data	314
Path Queries in the Movie Data	316
Item-Based Collaborative Filtering in Gremlin	318
Model 1: Counting Paths in the Recommendation Set	318
Model 2: NPS-Inspired and Jones and Model and	319
Model 3: Normalized NPS	322
Choosing Your Own Adventure: Movies and Graph Problems Edition	324
11. Simple Entity Resolution in Graphs	325
Chapter Preview: Merging Multiple Datasets into One Graph	325
Defining a Different Complex Problem: Entity Resolution	326
Seeing the Complex Problem	328
Analyzing the Two Movie Datasets	329
MovieLens Dataset	329
Kaggle Dataset	336
Development Schema	339
Matching and Merging the Movie Data	340
Our Matching Process	340
Resolving False Positives	343
False Positives Found in the MovieLens Dataset	343
Additional Errors Discovered in the Entity Resolution Process	344
Final Analysis of the Merging Process	346
The Role of Graph Structure in Merging Movie Data	347
12. Recommendations in Production.	349
Chapter Preview: Understanding Shortcut Edges, Precomputation, and	
Advanced Pruning Techniques	350
Shortcut Edges for Recommendations in Real Time	350
Where Our Development Process Doesn't Scale	351
How We Fix Scaling Issues: Shortcut Edges	352
Seeing What We Designed to Deliver in Production	353

Pruning: Different Ways to Precompute Shortcut Edges	354
Considerations for Updating Your Recommendations	356
Calculating Shortcut Edges for Our Movie Data	357
Breaking Down the Complex Problem of Precalculating Shortcut Edges	357
Addressing the Elephant in the Room: Batch Computation	362
Production Schema and Data Loading for Movie Recommendations	363
Production Schema for Movie Recommendations	364
Production Data Loading for Movie Recommendations	365
Recommendation Queries with Shortcut Edges	366
Confirming Our Edges Loaded Correctly	367
Production Recommendations for Our User	368
Understanding Response Time in Production by Counting Edge Partitions	372
Final Thoughts on Reasoning About Distributed Graph Query Performance	375
13. Epilogue	377
Where to Go from Here?	378
Graph Algorithms	378
Distributed Graphs	379
Graph Theory	380
Network Theory	380
Stay in Touch	382
Index	383
HIMSALT COLORS OF THE COLORS O	200