

Contents

Preface xv

Chapter 1 Introduction

- | | | | |
|--|----|----------------------------------|----|
| 1.1 Database System Applications | 1 | 1.7 Transaction Management | 15 |
| 1.2 Database Systems versus File Systems | 3 | 1.8 Database System Structure | 16 |
| 1.3 View of Data | 5 | 1.9 Application Architectures | 18 |
| 1.4 Data Models | 7 | 1.10 History of Database Systems | 18 |
| 1.5 Database Languages | 11 | 1.11 Summary | 21 |
| 1.6 Database Users and Administrators | 13 | Exercises | 23 |
| | | Bibliographical Notes | 24 |

PART 1 ■ DATA MODELS

Chapter 2 Entity-Relationship Model

- | | | | |
|--------------------------------------|----|--|----|
| 2.1 Basic Concepts | 27 | 2.9 Reduction of an E-R Schema to Tables | 62 |
| 2.2 Constraints | 33 | 2.10 The Unified Modeling Language UML | 68 |
| 2.3 Keys | 35 | 2.11 Summary | 70 |
| 2.4 Design Issues | 37 | Exercises | 72 |
| 2.5 Entity-Relationship Diagram | 42 | Bibliographical Notes | 77 |
| 2.6 Weak Entity Sets | 47 | | |
| 2.7 Extended E-R Features | 49 | | |
| 2.8 Design of an E-R Database Schema | 56 | | |

Chapter 3 Relational Model

- 3.1 Structure of Relational Databases 79
- 3.2 The Relational Algebra 89
- 3.3 Extended Relational-Algebra Operations 103
- 3.4 Modification of the Database 111
- 3.5 Views 113
- 3.6 The Tuple Relational Calculus 118
- 3.7 The Domain Relational Calculus 122
- 3.8 Summary 126
 - Exercises 127
 - Bibliographical Notes 131

PART 2 ■ RELATIONAL DATABASES

Chapter 4 SQL

- 4.1 Background 135
- 4.2 Basic Structure 137
- 4.3 Set Operations 144
- 4.4 Aggregate Functions 146
- 4.5 Null Values 148
- 4.6 Nested Subqueries 149
- 4.7 Views 154
- 4.8 Complex Queries 155
- 4.9 Modification of the Database 157
- 4.10 Joined Relations 163
- 4.11 Data-Definition Language 168
- 4.12 Embedded SQL 172
- 4.13 Dynamic SQL 175
- 4.14 Other SQL Features 180
- 4.15 Summary 182
 - Exercises 183
 - Bibliographical Notes 186

Chapter 5 Other Relational Languages

- 5.1 Query-by-Example 189
- 5.2 Datalog 203
- 5.3 User Interfaces and Tools 217
- 5.4 Summary 219
 - Exercises 220
 - Bibliographical Notes 223

Chapter 6 Integrity and Security

- 6.1 Domain Constraints 225
- 6.2 Referential Integrity 227
- 6.3 Assertions 232
- 6.4 Triggers 233
- 6.5 Security and Authorization 238
- 6.6 Authorization in SQL 244
- 6.7 Encryption and Authentication 248
- 6.8 Summary 250
 - Exercises 252
 - Bibliographical Notes 254

Chapter 7 Relational-Database Design

- | | | | |
|--|-----|--------------------------------------|-----|
| 7.1 First Normal Form | 257 | 7.7 Third Normal Form | 284 |
| 7.2 Pitfalls in Relational-Database Design | 258 | 7.8 Fourth Normal Form | 289 |
| 7.3 Functional Dependencies | 260 | 7.9 More Normal Forms | 293 |
| 7.4 Decomposition | 271 | 7.10 Overall Database Design Process | 293 |
| 7.5 Desirable Properties of Decomposition | 275 | 7.11 Summary | 297 |
| 7.6 Boyce–Codd Normal Form | 279 | Exercises | 299 |
| | | Bibliographical Notes | 303 |

PART 3 ■ OBJECT-BASED DATABASES AND XML

Chapter 8 Object-Oriented Databases

- | | | | |
|--------------------------------------|-----|-----------------------------|-----|
| 8.1 Need for Complex Data Types | 307 | 8.6 Persistent Java Systems | 330 |
| 8.2 The Object-Oriented Data Model | 308 | 8.7 Summary | 331 |
| 8.3 Object-Oriented Languages | 318 | Exercises | 332 |
| 8.4 Persistent Programming Languages | 318 | Bibliographical Notes | 333 |
| 8.5 Persistent C++ Systems | 322 | | |

Chapter 9 Object-Relational Databases

- | | | | |
|---------------------------------|-----|--|-----|
| 9.1 Nested Relations | 335 | 9.7 Object-Oriented versus Object-Relational | 356 |
| 9.2 Complex Types | 337 | 9.8 Summary | 357 |
| 9.3 Inheritance | 342 | Exercises | 358 |
| 9.4 Reference Types | 346 | Bibliographical Notes | 360 |
| 9.5 Querying with Complex Types | 348 | | |
| 9.6 Functions and Procedures | 351 | | |

Chapter 10 XML

- | | | | |
|--|-----|--------------------------|-----|
| 10.1 Background | 361 | 10.6 Storage of XML Data | 381 |
| 10.2 Structure of XML Data | 364 | 10.7 XML Applications | 384 |
| 10.3 XML Document Schema | 367 | 10.8 Summary | 386 |
| 10.4 Querying and Transformation | 372 | Exercises | 388 |
| 10.5 The Application Program Interface | 380 | Bibliographical Notes | 390 |

PART 4 ■ DATA STORAGE AND QUERYING

Chapter 11 Storage and File Structure

- 11.1 Overview of Physical Storage 422
 - Media 393
- 11.2 Magnetic Disks 396
- 11.3 RAID 402
- 11.4 Tertiary Storage 410
- 11.5 Storage Access 412
- 11.6 File Organization 415
- 11.7 Organization of Records in Files 422
- 11.8 Data-Dictionary Storage 426
- 11.9 Storage for Object-Oriented Databases 428
- 11.10 Summary 438
 - Exercises 440
 - Bibliographical Notes 443

Chapter 12 Indexing and Hashing

- 12.1 Basic Concepts 445
- 12.2 Ordered Indices 446
- 12.3 B⁺-Tree Index Files 453
- 12.4 B-Tree Index Files 464
- 12.5 Static Hashing 465
- 12.6 Dynamic Hashing 471
- 12.7 Comparison of Ordered Indexing and Hashing 477
- 12.8 Index Definition in SQL 479
- 12.9 Multiple-Key Access 480
- 12.10 Summary 487
 - Exercises 489
 - Bibliographical Notes 491

Chapter 13 Query Processing

- 13.1 Overview 493
- 13.2 Measures of Query Cost 495
- 13.3 Selection Operation 496
- 13.4 Sorting 501
- 13.5 Join Operation 503
- 13.6 Other Operations 514
- 13.7 Evaluation of Expressions 518
- 13.8 Summary 523
 - Exercises 525
 - Bibliographical Notes 526

Chapter 14 Query Optimization

- 14.1 Overview 529
- 14.2 Estimating Statistics of Expression Results 531
- 14.3 Transformation of Relational Expressions 537
- 14.4 Choice of Evaluation Plans 544
- 14.5 Materialized Views 553
- 14.6 Summary 557
 - Exercises 559
 - Bibliographical Notes 561

PART 5 ■ TRANSACTION MANAGEMENT

Chapter 15 Transactions

- | | | | |
|---|-----|------------------------------------|-----|
| 15.1 Transaction Concept | 565 | 15.7 Implementation of Isolation | 583 |
| 15.2 Transaction State | 568 | 15.8 Transaction Definition in SQL | 584 |
| 15.3 Implementation of Atomicity and Durability | 571 | 15.9 Testing for Serializability | 584 |
| 15.4 Concurrent Executions | 573 | 15.10 Summary | 586 |
| 15.5 Serializability | 576 | Exercises | 588 |
| 15.6 Recoverability | 582 | Bibliographical Notes | 590 |

Chapter 16 Concurrency Control

- | | | | |
|---------------------------------|-----|--------------------------------------|-----|
| 16.1 Lock-Based Protocols | 591 | 16.7 Insert and Delete Operations | 620 |
| 16.2 Timestamp-Based Protocols | 604 | 16.8 Weak Levels of Consistency | 623 |
| 16.3 Validation-Based Protocols | 607 | 16.9 Concurrency in Index Structures | 625 |
| 16.4 Multiple Granularity | 609 | 16.10 Summary | 629 |
| 16.5 Multiversion Schemes | 612 | Exercises | 632 |
| 16.6 Deadlock Handling | 615 | Bibliographical Notes | 636 |

Chapter 17 Recovery System

- | | | | |
|--|-----|---|-----|
| 17.1 Failure Classification | 639 | 17.8 Failure with Loss of Nonvolatile Storage | 663 |
| 17.2 Storage Structure | 640 | 17.9 Advanced Recovery Techniques | 664 |
| 17.3 Recovery and Atomicity | 644 | 17.10 Remote Backup Systems | 672 |
| 17.4 Log-Based Recovery | 645 | 17.11 Summary | 674 |
| 17.5 Shadow Paging | 653 | Exercises | 677 |
| 17.6 Recovery with Concurrent Transactions | 657 | Bibliographical Notes | 679 |
| 17.7 Buffer Management | 660 | | |

PART 6 ■ DATABASE SYSTEM ARCHITECTURE

Chapter 18 Database System Architectures

- | | | | |
|--|-----|-----------------------|-----|
| 18.1 Centralized and Client–Server Architectures | 683 | 18.5 Network Types | 701 |
| 18.2 Server System Architectures | 687 | 18.6 Summary | 703 |
| 18.3 Parallel Systems | 691 | Exercises | 705 |
| 18.4 Distributed Systems | 697 | Bibliographical Notes | 707 |

Chapter 19 Distributed Databases

- 19.1 Homogeneous and Heterogeneous Databases 709
- 19.2 Distributed Data Storage 710
- 19.3 Distributed Transactions 713
- 19.4 Commit Protocols 716
- 19.5 Concurrency Control in Distributed Databases 722
- 19.6 Availability 730
- 19.7 Distributed Query Processing 735
- 19.8 Heterogeneous Distributed Databases 738
- 19.9 Directory Systems 741
- 19.10 Summary 746
 - Exercises 749
 - Bibliographical Notes 752

Chapter 20 Parallel Databases

- 20.1 Introduction 755
- 20.2 I/O Parallelism 756
- 20.3 Interquery Parallelism 760
- 20.4 Intraquery Parallelism 761
- 20.5 Intraoperation Parallelism 762
- 20.6 Interoperation Parallelism 770
- 20.7 Design of Parallel Systems 772
- 20.8 Summary 773
 - Exercises 775
 - Bibliographical Notes 777

PART 7 ■ OTHER TOPICS

Chapter 21 Application Development and Administration

- 21.1 Web Interfaces to Databases 781
- 21.2 Performance Tuning 790
- 21.3 Performance Benchmarks 798
- 21.4 Standardization 802
- 21.5 E-Commerce 806
- 21.6 Legacy Systems 809
- 21.7 Summary 810
 - Exercises 812
 - Bibliographical Notes 815

Chapter 22 Advanced Querying and Information Retrieval

- 22.1 Decision-Support Systems 817
- 22.2 Data Analysis and OLAP 819
- 22.3 Data Mining 830
- 22.4 Data Warehousing 842
- 22.5 Information-Retrieval Systems 846
- 22.6 Summary 856
 - Exercises 859
 - Bibliographical Notes 861

Chapter 23 Advanced Data Types and New Applications

- 23.1 Motivation 863
- 23.2 Time in Databases 864
- 23.3 Spatial and Geographic Data 866
- 23.4 Multimedia Databases 877
- 23.5 Mobility and Personal Databases 880
- 23.6 Summary 885
 - Exercises 887
 - Bibliographical Notes 889

Chapter 24 Advanced Transaction Processing

- | | | | |
|--------------------------------------|-----|--|-----|
| 24.1 Transaction-Processing Monitors | 891 | 24.6 Transaction Management in
Multidatabases | 910 |
| 24.2 Transactional Workflows | 895 | 24.7 Summary | 914 |
| 24.3 Main-Memory Databases | 901 | Exercises | 916 |
| 24.4 Real-Time Transaction Systems | 903 | Bibliographical Notes | 917 |
| 24.5 Long-Duration Transactions | 904 | | |

PART 8 ■ CASE STUDIES**Chapter 25 Oracle**

- | | | | |
|--|-----|--|-----|
| 25.1 Database Design and Querying
Tools | 921 | 25.5 Concurrency Control and
Recovery | 940 |
| 25.2 SQL Variations and Extensions | 923 | 25.6 System Architecture | 942 |
| 25.3 Storage and Indexing | 925 | 25.7 Replication, Distribution, and External
Data | 945 |
| 25.4 Query Processing and
Optimization | 934 | 25.8 Database Administration Tools | 946 |
| | | Bibliographical Notes | 947 |

Chapter 26 IBM DB2 Universal Database

- | | | | |
|--|-----|--|-----|
| 26.1 Database Design and Querying
Tools | 950 | 26.6 System Architecture | 963 |
| 26.2 SQL Variations and Extensions | 951 | 26.7 Replication, Distribution, and External
Data | 965 |
| 26.3 Storage and Indexing | 953 | 26.8 Database Administration Tools | 965 |
| 26.4 Query Processing and
Optimization | 956 | 26.9 Summary | 967 |
| 26.5 Concurrency Control and
Recovery | 960 | Bibliographical Notes | 967 |

Chapter 27 Microsoft SQL Server

- | | | | |
|--|-----|---|------|
| 27.1 Management, Design, and Querying
Tools | 969 | 27.8 Distribution and Replication | 994 |
| 27.2 SQL Variations and Extensions | 975 | 27.9 Full-Text Queries on Relational
Data | 998 |
| 27.3 Storage and Indexing | 980 | 27.10 Data Warehousing and Analysis
Services | 999 |
| 27.4 Query Processing and
Optimization | 982 | 27.11 XML and Web Support | 1002 |
| 27.5 Concurrency and Recovery | 986 | 27.12 Summary | 1005 |
| 27.6 System Architecture | 991 | Bibliographical Notes | 1005 |
| 27.7 Data Access | 992 | | |

PART 9 ■ APPENDICES

Appendix A Network Model (contents online)

A.1 Basic Concepts	A1	A.6 DBTG Set-Processing Facility	A22
A.2 Data-Structure Diagrams	A2	A.7 Mapping of Networks to Files	A27
A.3 The DBTG CODASYL Model	A7	A.8 Summary	A31
A.4 DBTG Data-Retrieval Facility	A13	Exercises	A32
A.5 DBTG Update Facility	A20	Bibliographical Notes	A35

Appendix B Hierarchical Model (contents online)

B.1 Basic Concepts	B1	B.6 Mapping of Hierarchies to Files	B22
B.2 Tree-Structure Diagrams	B2	B.7 The IMS Database System	B24
B.3 Data-Retrieval Facility	B13	B.8 Summary	B25
B.4 Update Facility	B18	Exercises	B26
B.5 Virtual Records	B21	Bibliographical Notes	B29

Appendix C Advanced Relational Design (contents online)

C.1 Multivalued Dependencies	C1	C.4 Summary	C10
C.2 Join Dependencies	C5	Exercises	C10
C.3 Domain-Key Normal Form	C8	Bibliographical Notes	C11

Bibliography 1007

Index 1043