



Database System Concepts

Fifth Edition

**Abraham Silberschatz
Henry F. Korth
S. Sudarshan**

MCGRAW-HILL INTERNATIONAL EDITION



Contents

Preface xvii

Chapter 1 Introduction

1.1 Database-System Applications	1	1.9 Transaction Management	22
1.2 Purpose of Database Systems	3	1.10 Data Mining and Analysis	23
1.3 View of Data	5	1.11 Database Architecture	24
1.4 Database Languages	9	1.12 Database Users and Administrators	26
1.5 Relational Databases	11	1.13 History of Database Systems	28
1.6 Database Design	14	1.14 Summary	30
1.7 Object-Based and Semistructured Databases	19	Exercises	31
1.8 Data Storage and Querying	20	Bibliographical Notes	32

PART 1 ■ RELATIONAL DATABASES

Chapter 2. Relational Model

2.1 Structure of Relational Databases	37	2.5 Null Values	66
2.2 Fundamental Relational-Algebra Operations	46	2.6 Modification of the Database	68
2.3 Additional Relational-Algebra Operations	55	2.7 Summary	70
2.4 Extended Relational-Algebra Operations	60	Exercises	71
		Bibliographical Notes	73

Chapter 3 SQL

3.1 Background	75	3.8 Complex Queries	97
3.2 Data Definition	77	3.9 Views	99
3.3 Basic Structure of SQL Queries	80	3.10 Modification of the Database	103
3.4 Set Operations	87	3.11 Joined Relations**	110
3.5 Aggregate Functions	89	3.12 Summary	115
3.6 Null Values	91	Exercises	116
3.7 Nested Subqueries	93	Bibliographical Notes	120

Chapter 4 Advanced SQL

4.1 SQL Data Types and Schemas	121	4.7 Recursive Queries**	151
4.2 Integrity Constraints	126	4.8 Advanced SQL Features**	155
4.3 Authorization	133	4.9 Summary	158
4.4 Embedded SQL	134	Exercises	159
4.5 Dynamic SQL	137	Bibliographical Notes	162
4.6 Functions and Procedural Constructs**	145		

Chapter 5 Other Relational Languages

5.1 The Tuple Relational Calculus	163	5.5 Summary	194
5.2 The Domain Relational Calculus	168	Exercises	195
5.3 Query-by-Example	171	Bibliographical Notes	198
5.4 Datalog	180		

PART 2 ■ DATABASE DESIGN

Chapter 6 Database Design and the E-R Model

6.1 Overview of the Design Process	201	6.9 Reduction to Relational Schemas	241
6.2 The Entity-Relationship Model	204	6.10 Other Aspects of Database Design	248
6.3 Constraints	210	6.11 The Unified Modeling Language UML**	251
6.4 Entity-Relationship Diagrams	214	6.12 Summary	254
6.5 Entity-Relationship Design Issues	220	Exercises	256
6.6 Weak Entity Sets	225	Bibliographical Notes	261
6.7 Extended E-R Features	227		
6.8 Database Design for Banking Enterprise	236		

Chapter 7 Relational Database Design

7.1 Features of Good Relational Designs	263	7.6 Decomposition Using Multivalued Dependencies	293
7.2 Atomic Domains and First Normal Form	268	7.7 More Normal Forms	298
7.3 Decomposition Using Functional Dependencies	270	7.8 Database-Design Process	299
7.4 Functional-Dependency Theory	278	7.9 Modeling Temporal Data	302
7.5 Decomposition Using Functional Dependencies	288	7.10 Summary	304
		Exercises	306
		Bibliographical Notes	310

Chapter 8 Application Design and Development

8.1 User Interfaces and Tools	311	8.7 Authorization in SQL	335
8.2 Web Interfaces to Databases	314	8.8 Application Security	343
8.3 Web Fundamentals	315	8.9 Summary	350
8.4 Servlets and JSP	321	Exercises	352
8.5 Building Large Web Applications	326	Bibliographical Notes	357
8.6 Triggers	329		

PART 3 ■ OBJECT-BASED DATABASES AND XML

Chapter 9 Object-Based Databases

9.1 Overview	361	9.7 Implementing O-R Features	378
9.2 Complex Data Types	362	9.8 Persistent Programming Languages	379
9.3 Structured Types and Inheritance in SQL	365	9.9 Object-Oriented versus Object-Relational	387
9.4 Table Inheritance	369	9.10 Summary	388
9.5 Array and Multiset Types in SQL	371	Exercises	389
9.6 Object-Identity and Reference Types in SQL	376	Bibliographical Notes	393

Chapter 10 XML

10.1 Motivation	395	10.6 Storage of XML Data	421
10.2 Structure of XML Data	399	10.7 XML Applications	428
10.3 XML Document Schema	402	10.8 Summary	431
10.4 Querying and Transformation	408	Exercises	433
10.5 Application Program Interfaces to XML	420	Bibliographical Notes	436

PART 4 ■ DATA STORAGE AND QUERYING

Chapter 11 Storage and File Structure

11.1 Overview of Physical Storage	464
Media	441
11.2 Magnetic Disks	444
11.3 RAID	450
11.4 Tertiary Storage	458
11.5 Storage Access	460
11.6 File Organization	464
11.7 Organization of Records in Files	468
11.8 Data-Dictionary Storage	472
11.9 Summary	474
Exercises	476
Bibliographical Notes	478

Chapter 12 Indexing and Hashing

12.1 Basic Concepts	481
12.2 Ordered Indices	482
12.3 B ⁺ -Tree Index Files	489
12.4 B-Tree Index Files	501
12.5 Multiple-Key Access	502
12.6 Static Hashing	506
12.7 Dynamic Hashing	511
12.8 Comparison of Ordered Indexing and Hashing	518
12.9 Bitmap Indices	520
12.10 Index Definition in SQL	523
12.11 Summary	524
Exercises	526
Bibliographical Notes	529

Chapter 13 Query Processing

13.1 Overview	531
13.2 Measures of Query Cost	533
13.3 Selection Operation	534
13.4 Sorting	539
13.5 Join Operation	542
13.6 Other Operations	555
13.7 Evaluation of Expressions	559
13.8 Summary	563
Exercises	566
Bibliographical Notes	568

Chapter 14 Query Optimization

14.1 Overview	569
14.2 Transformation of Relational Expressions	571
14.3 Estimating Statistics of Expression Results	578
14.4 Choice of Evaluation Plans	584
14.5 Materialized Views**	593
14.6 Summary	598
Exercises	599
Bibliographical Notes	602

PART 5 ■ TRANSACTION MANAGEMENT

Chapter 15 Transactions

15.1 Transaction Concept	609	15.6 Recoverability	626
15.2 Transaction State	612	15.7 Implementation of Isolation	627
15.3 Implementation of Atomicity and Durability	615	15.8 Testing for Serializability	628
15.4 Concurrent Executions	617	15.9 Summary	630
15.5 Serializability	620	Exercises	632
		Bibliographical Notes	633

Chapter 16 Concurrency Control

16.1 Lock-Based Protocols	635	16.7 Insert and Delete Operations	664
16.2 Timestamp-Based Protocols	648	16.8 Weak Levels of Consistency	667
16.3 Validation-Based Protocols	651	16.9 Concurrency in Index Structures**	669
16.4 Multiple Granularity	653	16.10 Summary	673
16.5 Multiversion Schemes	656	Exercises	676
16.6 Deadlock Handling	659	Bibliographical Notes	680

Chapter 17 Recovery System

17.1 Failure Classification	683	17.7 Failure with Loss of Nonvolatile Storage	702
17.2 Storage Structure	684	17.8 Advanced Recovery Techniques**	703
17.3 Recovery and Atomicity	688	17.9 Remote Backup Systems	711
17.4 Log-Based Recovery	689	17.10 Summary	713
17.5 Recovery with Concurrent Transactions	697	Exercises	716
17.6 Buffer Management	699	Bibliographical Notes	718

PART 6 ■ DATA MINING AND INFORMATION RETRIEVAL

Chapter 18 Data Analysis and Mining

18.1 Decision-Support Systems	723	18.5 Summary	752
18.2 Data Analysis and OLAP	725	Exercises	754
18.3 Data Warehousing	736	Bibliographical Notes	756
18.4 Data Mining	739		

Chapter 19 Information Retrieval

19.1 Overview	759	19.7 Web Search Engines	771
19.2 Relevance Ranking Using Terms	761	19.8 Information Retrieval and Structured	
19.3 Relevance Using Hyperlinks	763	Data	772
19.4 Synonyms, Homonyms and		19.9 Directories	773
Ontologies	768	19.10 Summary	776
19.5 Indexing of Documents	769	Exercises	777
19.6 Measuring Retrieval Effectiveness	770	Bibliographical Notes	779

PART 7 ■ SYSTEM ARCHITECTURE

Chapter 20 Database-System Architectures

20.1 Centralized and Client–Server		20.5 Network Types	801
Architectures	783	20.6 Summary	803
20.2 Server System Architectures	786	Exercises	805
20.3 Parallel Systems	790	Bibliographical Notes	807
20.4 Distributed Systems	797		

Chapter 21 Parallel Databases

21.1 Introduction	809	21.6 Interoperation Parallelism	824
21.2 I/O Parallelism	810	21.7 Design of Parallel Systems	826
21.3 Interquery Parallelism	814	21.8 Summary	827
21.4 Intraquery Parallelism	815	Exercises	829
21.5 Intraoperation Parallelism	816	Bibliographical Notes	831

Chapter 22 Distributed Databases

22.1 Homogeneous and Heterogeneous		22.7 Distributed Query Processing	859
Databases	833	22.8 Heterogeneous Distributed	
22.2 Distributed Data Storage	834	Databases	862
22.3 Distributed Transactions	837	22.9 Directory Systems	865
22.4 Commit Protocols	840	22.10 Summary	870
22.5 Concurrency Control in Distributed		Exercises	873
Databases	846	Bibliographical Notes	876
22.6 Availability	854		

PART 8 ■ OTHER TOPICS**Chapter 23 Advanced Application Development**

23.1 Performance Tuning	881	23.5 Summary	900
23.2 Performance Benchmarks	891	Exercises	902
23.3 Standardization	895	Bibliographical Notes	903
23.4 Application Migration	899		

Chapter 24 Advanced Data Types and New Applications

24.1 Motivation	905	24.5 Mobility and Personal Databases	922
24.2 Time in Databases	906	24.6 Summary	927
24.3 Spatial and Geographic Data	908	Exercises	929
24.4 Multimedia Databases	919	Bibliographical Notes	931

Chapter 25 Advanced Transaction Processing

25.1 Transaction-Processing Monitors	933	25.7 Transaction Management in Multidatabases	956
25.2 Transactional Workflows	938	25.8 Summary	959
25.3 E-Commerce	944	Exercises	962
25.4 Main-Memory Databases	947	Bibliographical Notes	964
25.5 Real-Time Transaction Systems	949		
25.6 Long-Duration Transactions	950		

PART 9 ■ CASE STUDIES**Chapter 26 PostgreSQL**

26.1 Introduction	967	26.5 Storage and Indexing	988
26.2 User Interfaces	968	26.6 Query Processing and Optimization	991
26.3 SQL Variations and Extensions	971	26.7 System Architecture	994
26.4 Transaction Management in PostgreSQL	979	Bibliographical Notes	995

Chapter 27 Oracle

27.1 Database Design and Querying Tools	997	27.6 System Architecture	1019
27.2 SQL Variations and Extensions	999	27.7 Replication, Distribution, and External Data	1022
27.3 Storage and Indexing	1001	27.8 Database Administration Tools	1024
27.4 Query Processing and Optimization	1010	27.9 Data Mining	1025
27.5 Concurrency Control and Recovery	1017	Bibliographical Notes	1026

Chapter 28 IBM DB2 Universal Database

28.1 Overview	1027	28.9 Tools and Utilities	1048
28.2 Database-Design Tools	1029	28.10 Concurrency Control and Recovery	1050
28.3 SQL Variations and Extensions	1029	28.11 System Architecture	1052
28.4 Storage and Indexing	1034	28.12 Replication, Distribution and External Data	1053
28.5 Multidimensional Clustering	1037	28.13 Business Intelligence Features	1054
28.6 Query Processing and Optimization	1040	Bibliographical Notes	1055
28.7 Materialized Query Tables	1045		
28.8 Autonomic Features in DB2	1047		

Chapter 29 Microsoft SQL Server

29.1 Management, Design, and Querying Tools	1057	29.8 Distributed Heterogeneous Query Processing	1081
29.2 SQL Variations and Extensions	1062	29.9 Replication	1082
29.3 Storage and Indexing	1066	29.10 Server Programming in .NET	1084
29.4 Query Processing and Optimization	1069	29.11 XML Support in SQL Server 2005	1089
29.5 Concurrency and Recovery	1074	29.12 SQL Server Service Broker	1094
29.6 System Architecture	1078	29.13 Data Warehouse and Business Intelligence	1096
29.7 Data Access	1080	Bibliographical Notes	1100

PART 10 ■ 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 Database 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 1101

Index 1129