

AN INTRODUCTION TO

Database Systems

SEVENTH
EDITION

C. J. Date



ADDISON-WESLEY PUBLISHING COMPANY

*Reading, Massachusetts • Menlo Park, California • New York • Harlow, England
Don Mills, Ontario • Sydney • Mexico City • Madrid • Amsterdam*

Technische Universität Darmstadt
FACHBEREICH INFORMATIK
B I B L I O T H E K

Inventar-Nr.: 402-00398

Sachgebiete: _____

Standort: _____

Contents

Preface to the Seventh Edition xvii

PART I PRELIMINARIES 1

CHAPTER 1 An Overview of Database Management 2

- 1.1 Introduction 2
- 1.2 What is a database system? 5
- 1.3 What is a database? 9
- 1.4 Why database? 15
- 1.5 Data independence 19
- 1.6 Relational systems and others 25
- 1.7 Summary 27
- Exercises 28
- References and bibliography 30
- Answers to selected exercises 30

CHAPTER 2 Database System Architecture 33

- 2.1 Introduction 33
- 2.2 The three levels of the architecture 33
- 2.3 The external level 37
- 2.4 The conceptual level 39
- 2.5 The internal level 40
- 2.6 Mappings 40
- 2.7 The database administrator 41
- 2.8 The database management system 43
- 2.9 The data communications manager 47
- 2.10 Client/server architecture 48
- 2.11 Utilities 50
- 2.12 Distributed processing 50
- 2.13 Summary 54

Exercises	55
References and bibliography	56

CHAPTER 3 An Introduction to Relational Databases 58

3.1	Introduction	58
3.2	An informal look at the relational model	58
3.3	Relations and relvars	63
3.4	What relations mean	65
3.5	Optimization	67
3.6	The catalog	69
3.7	Base relvars and views	71
3.8	Transactions	75
3.9	The suppliers and parts database	76
3.10	Summary	78
	Exercises	80
	References and bibliography	81
	Answers to selected exercises	82

CHAPTER 4 An Introduction to SQL 83

4.1	Introduction	83
4.2	Overview	84
4.3	The catalog	87
4.4	Views	88
4.5	Transactions	89
4.6	Embedded SQL	89
4.7	SQL is not perfect	98
4.8	Summary	98
	Exercises	99
	References and bibliography	101
	Answers to selected exercises	106

PART II THE RELATIONAL MODEL 109

CHAPTER 5 Domains, Relations, and Base Relvars 111

5.1	Introduction	111
5.2	Domains	112
5.3	Relation values	123
5.4	Relation variables	129

5.5	SQL facilities	134
5.6	Summary	137
	Exercises	139
	References and bibliography	141
	Answers to selected exercises	144
CHAPTER 6	Relational Algebra	150
6.1	Introduction	150
6.2	Closure revisited	152
6.3	Syntax	154
6.4	Semantics	156
6.5	Examples	167
6.6	What is the algebra for?	169
6.7	Additional operators	171
6.8	Grouping and ungrouping	179
6.9	Relational comparisons	182
6.10	Summary	184
	Exercises	184
	References and bibliography	187
	Answers to selected exercises	190
CHAPTER 7	Relational Calculus	198
7.1	Introduction	198
7.2	Tuple calculus	200
7.3	Examples	208
7.4	Calculus <i>vs.</i> algebra	210
7.5	Computational capabilities	215
7.6	Domain calculus	216
7.7	SQL facilities	218
7.8	Summary	228
	Exercises	229
	References and bibliography	231
	Answers to selected exercises	233
CHAPTER 8	Integrity	249
8.1	Introduction	249
8.2	Type constraints	251
8.3	Attribute constraints	252
8.4	Relvar constraints	253

8.5	Database constraints	254
8.6	<i>The Golden Rule</i>	254
8.7	State <i>vs.</i> transition constraints	256
8.8	Keys	258
8.9	SQL facilities	267
8.10	Summary	271
	Exercises	272
	References and bibliography	274
	Answers to selected exercises	280

CHAPTER 9 Views 289

9.1	Introduction	289
9.2	What are views for?	292
9.3	View retrievals	295
9.4	View updates	297
9.5	Snapshots (a digression)	313
9.6	SQL facilities	314
9.7	Summary	316
	Exercises	317
	References and bibliography	319
	Answers to selected exercises	321

PART III DATABASE DESIGN 327

CHAPTER 10 Functional Dependencies 330

10.1	Introduction	330
10.2	Basic definitions	331
10.3	Trivial and nontrivial dependencies	334
10.4	Closure of a set of dependencies	334
10.5	Closure of a set of attributes	336
10.6	Irreducible sets of dependencies	337
10.7	Summary	340
	Exercises	341
	References and bibliography	342
	Answers to selected exercises	344

CHAPTER 11 Further Normalization I: 1NF, 2NF, 3NF, BCNF 348

11.1	Introduction	348
11.2	Nonloss decomposition and functional dependencies	352

11.3	First, second, and third normal forms	356
11.4	Dependency preservation	363
11.5	Boyce/Codd normal form	366
11.6	A note on relation-valued attributes	372
11.7	Summary	374
	Exercises	375
	References and bibliography	377
	Answers to selected exercises	379
CHAPTER 12	Further Normalization II: Higher Normal Forms	389
12.1	Introduction	389
12.2	Multi-valued dependencies and fourth normal form	389
12.3	Join dependencies and fifth normal form	394
12.4	The normalization procedure summarized	399
12.5	A note on denormalization	401
12.6	Orthogonal design (a digression)	404
12.7	Other normal forms	407
12.8	Summary	408
	Exercises	409
	References and bibliography	410
	Answers to selected exercises	416
CHAPTER 13	Semantic Modeling	419
13.1	Introduction	419
13.2	The overall approach	421
13.3	The E/R model	424
13.4	E/R diagrams	427
13.5	Database design with the E/R model	430
13.6	A brief analysis	434
13.7	Summary	437
	Exercises	439
	References and bibliography	440

PART IV TRANSACTION MANAGEMENT 453

CHAPTER 14	Recovery	454
14.1	Introduction	454
14.2	Transactions	455

14.3	Transaction recovery	457
14.4	System recovery	460
14.5	Media recovery	462
14.6	Two-phase commit	462
14.7	SQL facilities	464
14.8	Summary	465
	Exercises	466
	References and bibliography	466
	Answers to selected exercises	471

CHAPTER 15 Concurrency 473

15.1	Introduction	473
15.2	Three concurrency problems	474
15.3	Locking	477
15.4	The three concurrency problems revisited	478
15.5	Deadlock	481
15.6	Serializability	482
15.7	Isolation levels	484
15.8	Intent locking	486
15.9	SQL facilities	488
15.10	Summary	490
	Exercises	491
	References and bibliography	493
	Answers to selected exercises	499

PART V FURTHER TOPICS 503

CHAPTER 16 Security 504

16.1	Introduction	504
16.2	Discretionary access control	506
16.3	Mandatory access control	512
16.4	Statistical databases	515
16.5	Data encryption	520
16.6	SQL facilities	525
16.7	Summary	528
	Exercises	529
	References and bibliography	530
	Answers to selected exercises	532

CHAPTER 17	Optimization	537
17.1	Introduction	537
17.2	A motivating example	539
17.3	An overview of query processing	540
17.4	Expression transformation	544
17.5	Database statistics	550
17.6	A divide and conquer strategy	551
17.7	Implementing the relational operators	554
17.8	Summary	560
	Exercises	561
	References and bibliography	564
	Answers to selected exercises	582
CHAPTER 18	Missing Information	584
18.1	Introduction	584
18.2	An overview of the 3VL approach	585
18.3	Some consequences of the foregoing scheme	591
18.4	Nulls and keys	595
18.5	Outer join (a digression)	597
18.6	Special values	600
18.7	SQL facilities	601
18.8	Summary	604
	Exercises	606
	References and bibliography	608
	Answers to selected exercises	611
CHAPTER 19	Type Inheritance	613
19.1	Introduction	613
19.2	Type hierarchies	617
19.3	Polymorphism and substitutability	620
19.4	Variables and assignments	624
19.5	Specialization by constraint	628
19.6	Comparisons	630
19.7	Operators, versions, and signatures	635
19.8	Is a circle an ellipse?	639
19.9	Specialization by constraint revisited	643
19.10	Summary	645
	Exercises	646
	References and bibliography	648
	Answers to selected exercises	649

CHAPTER 20	Distributed Databases	651
20.1	Introduction	651
20.2	Some preliminaries	651
20.3	The twelve objectives	656
20.4	Problems of distributed systems	664
20.5	Client/server systems	675
20.6	DBMS independence	678
20.7	SQL facilities	683
20.8	Summary	684
	Exercises	685
	References and bibliography	686
CHAPTER 21	Decision Support	694
21.1	Introduction	694
21.2	Aspects of decision support	695
21.3	Database design for decision support	697
21.4	Data preparation	706
21.5	Data warehouses and data marts	709
21.6	Online analytical processing	715
21.7	Data mining	722
21.8	Summary	724
	Exercises	725
	References and bibliography	726
	Answers to selected exercises	729
CHAPTER 22	Temporal Databases	730
22.1	Introduction	730
22.2	Temporal data	731
22.3	What is the problem?	736
22.4	Intervals	742
22.5	Interval types	744
22.6	Scalar operators on intervals	746
22.7	Aggregate operators on intervals	747
22.8	Relational operators involving intervals	748
22.9	Constraints involving intervals	754
22.10	Update operators involving intervals	757
22.11	Database design considerations	759
22.12	Summary	762
	Exercises	763

References and bibliography	764
Answers to selected exercises	766

CHAPTER 23	Logic-Based Databases	769
23.1	Introduction	769
23.2	Overview	769
23.3	Propositional calculus	772
23.4	Predicate calculus	777
23.5	A proof-theoretic view of databases	784
23.6	Deductive database systems	787
23.7	Recursive query processing	793
23.8	Summary	798
	Exercises	801
	References and bibliography	802
	Answers to selected exercises	808

PART VI OBJECT AND OBJECT/RELATIONAL DATABASES 811

CHAPTER 24	Object Databases	812
24.1	Introduction	812
24.2	Objects, classes, methods, and messages	816
24.3	A closer look	821
24.4	A cradle-to-grave example	829
24.5	Miscellaneous issues	839
24.6	Summary	847
	Exercises	850
	References and bibliography	851
	Answers to selected exercises	859

CHAPTER 25	Object/Relational Databases	862
25.1	Introduction	862
25.2	<i>The First Great Blunder</i>	865
25.3	<i>The Second Great Blunder</i>	872
25.4	Implementation issues	875
25.5	Benefits of true <i>rapprochement</i>	877
25.6	Summary	879
	References and bibliography	880

APPENDIXES 887

APPENDIX A SQL Expressions 888

- A.1 Introduction 888
- A.2 Table expressions 888
- A.3 Conditional expressions 894
- A.4 Scalar expressions 898

APPENDIX B An Overview of SQL3 900

- B.1 Introduction 900
- B.2 New data types 901
- B.3 Type inheritance 906
- B.4 Reference types 907
- B.5 Subtables and supertables 910
- B.6 Other features 912

APPENDIX C Abbreviations, Acronyms, and Symbols 916

Index 923