

Chapter 2 The Relational Model of Data



Objectives

- Understand what is the relational model and database design basing relational model.
- Conceptualize data using the relational model.
- Understand what basic relational algebra operators under set semantics.
- Express queries using relational algebra.



Contents

- 2.1 An Overview of Data Models
- 2.2 Basics of the Relational Model
- 2.3 An Algebraic Query Language



2.1 An Overview of Data Models

- Data model: a collection of concepts for describing data, including 3 parts:
 - Structure of the data
 - Ex: arrays or objects
 - Operations on the data
 - Queries and modification on data
 - Constraints on the data
 - Limitations on the data



2.1 An Overview of Data Models

- The relational model, including object-relational extensions
- The semi-structured data model, including XML and related standards
- Semi-structured data resembles trees or graphs rather than tables or arrays
- XML, a way to represent data by hierarchically nested tagged elements
- Operations involve following paths in tree from an element to one or more of its nested sub elements, and so on
- Constraints involve the data type of values associated with a nested tag



2.1 An Overview of Data Models

```
<?xml version="1.0"?>
<!DOCTYPE PARTS SYSTEM "parts.dtd">
<?xml-stylesheet type="text/css" href="xmlpartsstyle.css"?>
<PARTS>
   <TITLE>Computer Parts</TITLE>
   <PART>
      <ITEM>Motherboard</ITEM>
      <MANUFACTURER>ASUS</MANUFACTURER>
      <MODEL>P3B-F</MODEL>
      <COST> 123.00</COST>
   </PART>
   <PART>
      <ITEM>Video Card</ITEM>
      <MANUFACTURER>ATI</MANUFACTURER>
      <MODEL>All-in-Wonder Pro</MODEL>
      <COST> 160.00</COST>
   </PART>
   <PART>
      <ITEM>Sound Card</ITEM>
      <MANUFACTURER>Creative Labs</MANUFACTURER>
      <MODEL>Sound Blaster Live</MODEL>
      <COST> 80.00</COST>
   </PART>
   <PART>
      <ITEMD inch Monitor</ITEM>
      <MANUFACTURER>LG Electronics/MANUFACTURER>
      <MODEL> 995E</MODEL>
      <COST> 290.00</COST>
   </PART>
</PARTS>
```



2.2 Basics of the Relational Model

Relational model

- A relation is made up from 2 parts:
 - Schema: specifies name of relation, name of attributes and domain/type of one's.
 - Ex: Student(StudentID: string, Name: string, Registered: int, CounsellorNo: int, Region: int)
 - Instance: a table with rows and columns
 - Rows ~ cardinality; columns ~ degree/arity

 A simple thinking: a relation as a set of distinct rows or tuples

relation name —	Student		attributes	_		relation
primary key	Studentld	Name	Registered	CounsellorNo	Region	
A	s01	Akeroyd	1993	3158	3	
	s02	Thompson	1998	5212	4	
0.0.23	s05	Ellis	1997	5212	4	─ a tuple
cardinality (6)	s07	Gillies	1996	3158	3	
	s09	Reeves	1998	5212	4	
. ↓	s10	Urbach	1997	5212	4	
	•		degree (5)			<u>→</u>



2.2 Basics of the Relational Model

- Database schema: a set of schemas for the relations of a database
- An example of DB schema:
 - Sailors(sid: integer, sname: string, rating: integer, age:real)
 - Boats(bid:integer, bname: string, color: string)
 - Reserves(sid: integer, bid: integer , day: date)



2.2 Basics of the Relational Model

- Key attribute
- Non-key attribute
- Multi-valued attribute
- Derived- attribute
- Candidate key
- Primary key
- Foreign key



2.3 An Algebraic Query Language

Relational Algebra

- An algebra consists of operators and atomic operands
- Relational algebra is an example of an algebra, its atomic operands are
 - Variables that stand for relations
 - Constants, which are finite relations
- Relational algebra is a set of operations on relations
- Operations operate on one or more relations to create new relation



2.3 An Algebraic Query Language

Relational algebra fall into four classes

- Set operations union, intersection, difference
- Selection and projection
- Cartesian product and joins
- Rename



2.3 An Algebraic Query Language

Set operations

Union

$$\mathbf{R} \cup \mathbf{S} = \{ t \mid t \in \mathbf{R} \lor t \in \mathbf{S} \}$$

Intersection

$$\mathbf{R} \cap \mathbf{S} = \{ t \mid t \in \mathbf{R} \land t \in \mathbf{S} \}$$

Difference

$$\mathbf{R} \setminus \mathbf{S} = \{ t \mid t \in \mathbf{R} \land t \notin \mathbf{S} \}$$

 Intersection can be expressed in terms of set difference

$$R \cap S = R \setminus (R \setminus S)$$

R and S must be 'type compatible'

- The same number of attributes
- The domain of corresponding attributes must be compatible



Set operations- Example

name	address	gender	birthdate
Carrie Fisher	123 Maple St., Holywood	F	9/9/99
Mark Hamill	456 Oak Rd., Brentwood	M	8/8/88

Relation R

name	address	gender	birthdate
Carrie Fisher	123 Maple St., Holywood	F	9/9/99
Harrison Ford	789 Palm Dr., Beverly Hills	M	8/8/88

Relation S



Set operations- Example

$R \cup S$	name	address	gender	birthdate
	Carrie Fisher	123 Maple St., Holywood	F	9/9/99
	Mark Hamill	456 Oak Rd., Brentwood	M	8/8/88
	Harrison Ford	789 Palm Dr., Beverly Hills	M	8/8/88
$R \cap S$	name	address	gender	birthdate
	Carrie Fisher	123 Maple St., Holywood	F	9/9/99
R \ S	name	address	gender	birthdate
	Mark Hamill	456 Oak Rd., Brentwood	M	8/8/88



Selection and projection

Selection

- R1 := $\sigma_C(R2)$ with C illustrated conditions

- ex:
$$\sigma_{}(\sigma_{}(R)) = \sigma_{}(\sigma_{}(R)) = \sigma_{}(R) = \sigma_{}(R)$$
 Movies

title	year	length	genre
Gone With the Wind	1939	231	Drama
Star Wars	1977	124	Scifi
Wayne's World	1992	95	Comedy

$\sigma_{length \ge 100}$ (Movies)

title	year	length	genre
Gone With the Wind	1939	231	Drama
Star Wars	1977	124	Scifi



Selection and projection

- Projection S := $\Pi_{A1,A2,...,An}$ (R)
 - A1,A2,...,An are attributes of R
 - S relation schema S(A1,A2,...,An)

Movies

title	year	length	genre
Star Wars	1977	124	Scifi
Galaxy Quest	1999	104	Comedy
Wayne's World	1992	95	Comedy

$\pi_{\textit{title,year,length}}(\mathsf{Movies})$

title	year	length
Star Wars	1977	124
Galaxy Quest	1999	104
Wayne's World	1992	95

π_{genre} (Movies)

genre
Scifi
Comedy



Cartesian product and joins

Cartesian product R3 := R1 X R2

Relation R

Α	В
1	2
3	4

Relation S

В	С	D
2	5	6
4	7	8
9	10	11

Cartesian Product R X S

Α	R.B	S.B	С	D
1	2	2	5	6
1	2	4	7	8
1	2	9	10	11
3	4	2	5	6
3	4	4	7	8
3	4	9	10	11



Cartesian product and joins

•theta joins R3 := R1 $\bowtie_{< join condition>}$ R2

Α	В	С
1	2	3
6	7	8
9	7	8

Relation U

В	С	D
2	3	4
2	3	5
7	8	10

Relation V

Α	U.B	U.C	V.B	V.C	D
1	2	3	2	3	4
1	2	3	2	3	5
1	2	3	7	8	10
6	7	8	7	8	10
9	7	8	7	8	10

Figure 2.17: Result of U \bowtie _{A<D} V

Α	U.B	U.C	V.B	V.C	D
1	2	3	7	8	10

Result of U \bowtie $_{A < D \text{ AND } U, B \neq V, B}$ V



Cartesian product and joins

Natural join R3 := R1 \bowtie R2

Relation R

Α	В
1	2
3	4

Relation S

В	С	D
2	5	6
4	7	8
9	10	11

Natural Join R ⋈ S

Α	В	С	D
1	2	5	6
3	4	7	8



Rename

- The ρ operation gives a new schema to a relation
- $\rho_{S(A1,...,An)}(R)$ makes S be a relation with attributes A1,...,An and the same tuples as R
- Simplified notation: S:=R (A1,A2,...,An)

Relation R

Α	В
1	2
3	4

Relation S

В	С	D
2	5	6
4	7	8
9	10	11

 $R \times \rho_{S(X,C,D)}(S)$

Α	В	Х	С	D
1	2	2	5	6
1	2	4	7	8
1	2	9	10	11
3	4	2	5	6
3	4	4	7	8
3	4	9	10	11

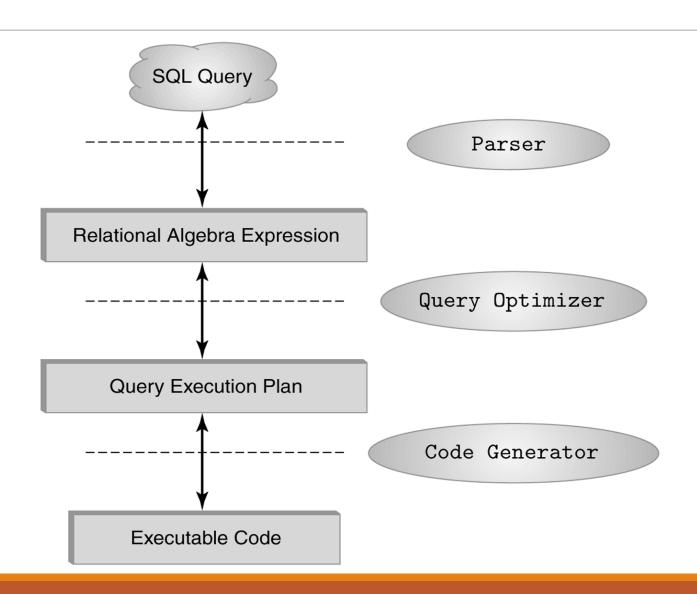


Relational Expression

- How we need relational expression
- Relational algebra allows us to form expressions
- Relational expression is constructed by applying operations to the result of other operations
- Expressions can be presented as expression tree



The role of relational algebra in a DBMS





Relational Expression

Example: What are the titles and years of movies made by Fox that are at least 100 minutes long?

- (1) Select those Movies tuples that have length
 ≥ 100
- (2) Select those Movies tuples that have studioName='Fox'
- (3) Compute the intersection of (1) and (2)
- (4) Project the relation from (3) onto attributes title and year



Relational Expression

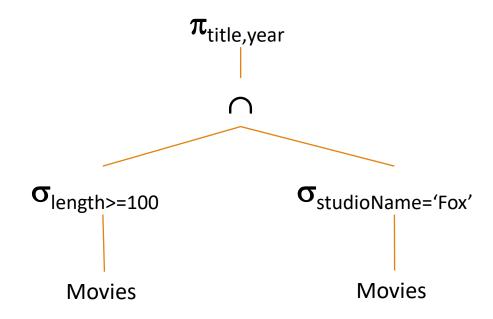


Figure 2.18: Expression tree for a relational algebra expression

$$\begin{split} &\pi_{\text{title,year}}(\sigma_{\text{length}\geq 100} \text{ (Movies)} \cap \sigma_{\text{studioName='Fox'}} \text{ (Movies))} \\ &\pi_{\text{title,year}}(\sigma_{\text{length}\geq 100 \text{ AND studioName='Fox'}} \text{ (Movies))} \end{split}$$



Exercise

```
Product(maker, model, type)
PC(model, speed, ram, hd, price)
Laptop(model, speed, ram, hd, screen, price)
Printer(model, color, type, price)
```

- a) What PC models have a speed of at least 3.00?
- b) Which manufacturers make laptops with a hard disk of at least 100GB?
- c) Find the model number and price of all products (of any type) made by manufacturer B.
- d) Find the model numbers of all color laser printers.
- e) Find those manufacturers that sell Laptops, but not PC's.