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

- **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

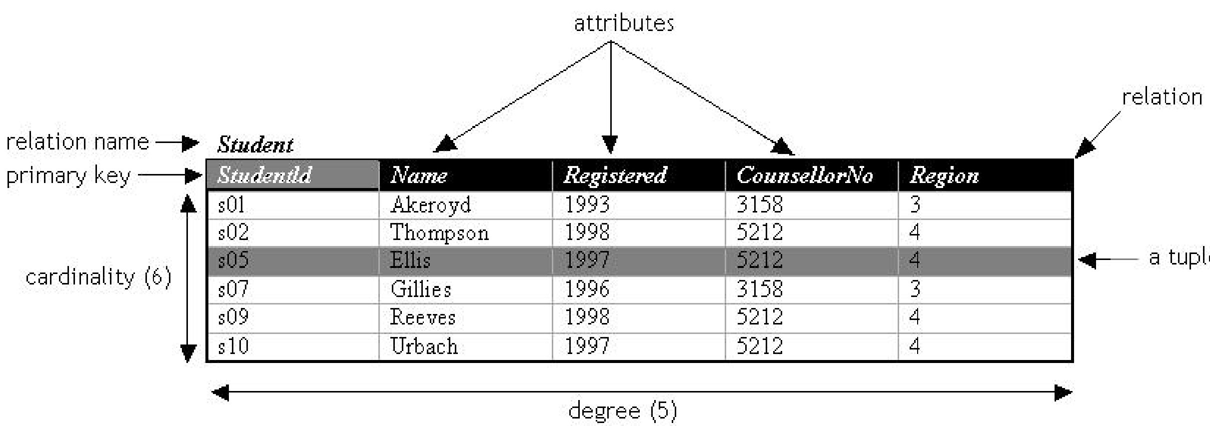
- The relational model, including object-relational extensions
- The semi-structured data model, including XML and related standards
- Semi-structured data resembles trees or graphs rather than tables or arrays
- XML, a way to represent data by hierarchically nested tagged elements
- Operations involve 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>
      <ITEM⊠ 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**



StudentId	Name	Registered	CounsellorNo	Region
s01	Akeroyd	1993	3158	3
s02	Thompson	1998	5212	4
s05	Ellis	1997	5212	4
s07	Gillies	1996	3158	3
s09	Reeves	1998	5212	4
s10	Urbach	1997	5212	4

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

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

- Intersection

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

- Difference

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

- Intersection can be expressed in terms of set difference

$$\mathbf{R} \cap \mathbf{S} = \mathbf{R} \setminus (\mathbf{R} \setminus \mathbf{S})$$

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

$R \setminus S$

name	*address*	*gender*	*birthdate*
Mark Hamill	456 Oak Rd., Brentwood	M	8/8/88

Selection and projection

- **Selection**

  - R1 := σ_C(R2) with C illustrated conditions

  - **ex:** $\sigma_{<C1>}(\sigma_{<C2>}(R)) = \sigma_{<C2>}(\sigma_{<C1>}(R)) = \sigma_{<C1>\ AND\ <C2>}$

Movies

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

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

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

Selection and projection

- Projection S := $\pi_{A1,A2,\ldots,An}$ (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

$\pi_{title,year,length}$(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

A	B
1	2
3	4

Relation S

B	C	D
2	5	6
4	7	8
9	10	11

Cartesian Product R X S

A	R.B	S.B	C	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 $\bowtie_{\text{<join condition>}}$ R2

A	B	C
1	2	3
6	7	8
9	7	8

Relation U

B	C	D
2	3	4
2	3	5
7	8	10

Relation V

A	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

A	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

A	B
1	2
3	4

Relation S

B	C	D
2	5	6
4	7	8
9	10	11

Natural Join R $\bowtie$ S

A	B	C	D
1	2	5	6
3	4	7	8

Rename

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

Relation R

A	B
1	2
3	4

Relation S

B	C	D
2	5	6
4	7	8
9	10	11

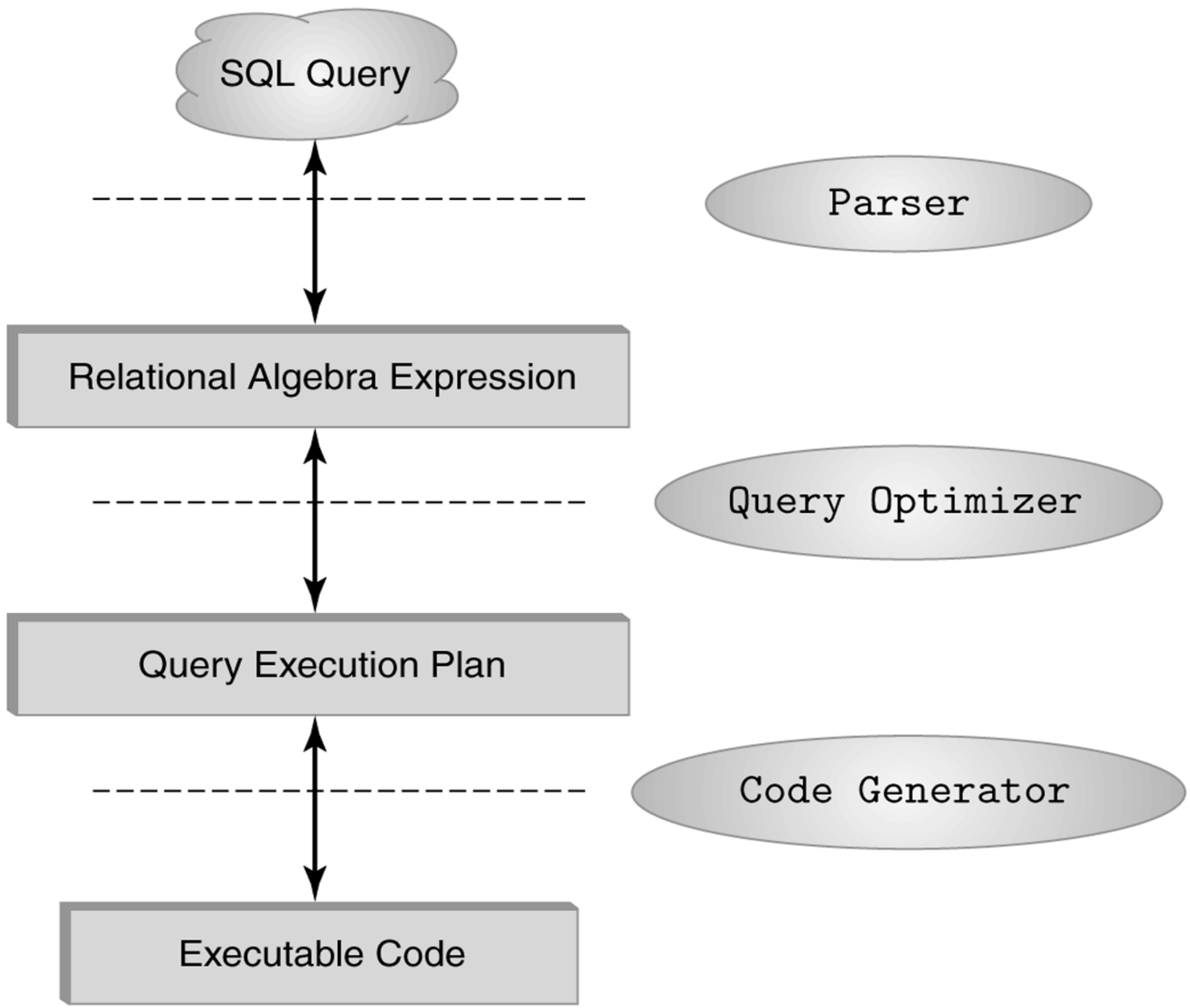
R X $\rho_{S(X,C,D)}$ (S)

A	B	X	C	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 $\geq$ 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

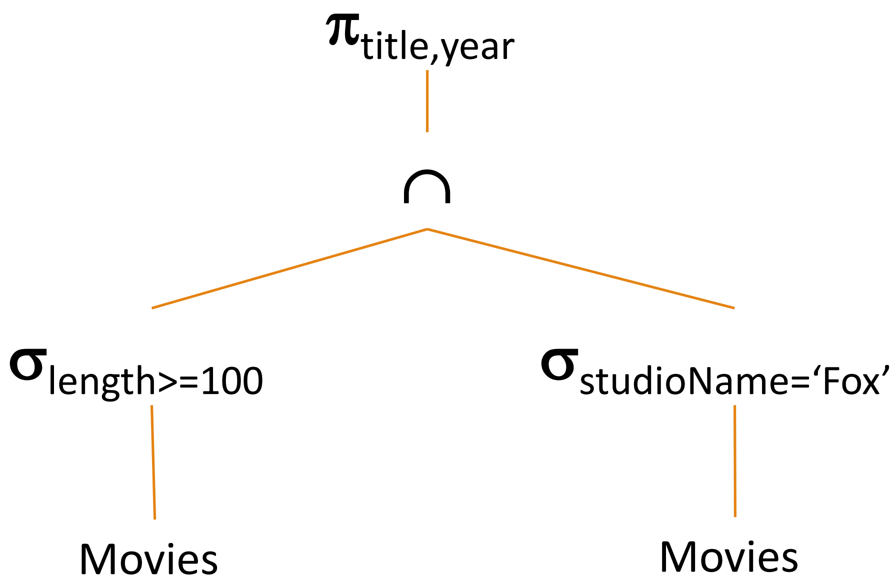


Figure 2.18: Expression tree for a relational algebra expression

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

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

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.