Relational Algebra and SQL
Part 1: Relational Algebra

Chapter 6

Relational Query Languages

- Languages for describing queries on a relational database
- *Structured Query Language* (SQL)
  - Predominant application-level query language
  - Declarative
- *Relational Algebra*
  - Intermediate language used within DBMS
  - Procedural

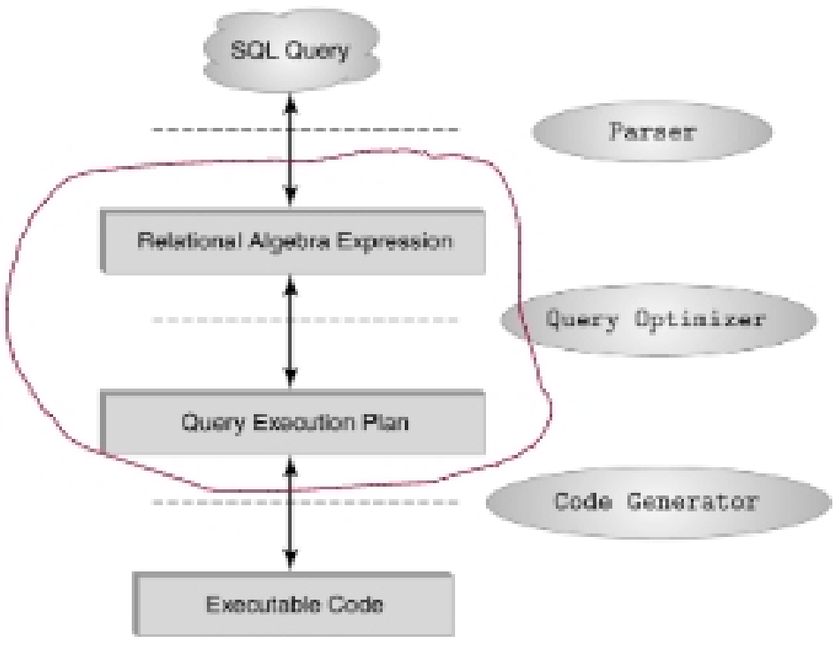
What is an Algebra?

- A language based on operators and a domain of values
- Operators map values taken from the domain into other domain values
- Hence, an expression involving operators and arguments produces a value in the domain
- When the domain is a set of all relations (and the operators are as described later), we get the *relational algebra*
- We refer to the expression as a *query* and the value produced as the *query result*

Relational Algebra

- *Domain*: set of relations
- *Basic operators*: select, project, union, set difference, Cartesian product
- *Derived operators*: set intersection, division, join
- *Procedural*: Relational expression specifies query by describing an algorithm (the sequence in which operators are applied) for determining the result of an expression

The Role of Relational Algebra in a DBMS



Select Operator

- Produce table containing subset of rows of argument table satisfying condition

  $\sigma_{condition}(relation)$

- Example:

Person

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
1123	John	123 Main	coins
5556	Mary	7 Lake Dr	hiking
9876	Bart	5 Pine St	stamps

$\sigma_{Hobby='stamps'}(\text{Person})$

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
9876	Bart	5 Pine St	stamps

Selection Condition

- Operators: $<, \leq, \geq, >, =, \neq$
- Simple selection condition:
  - *<attribute> operator <constant>*
  - *<attribute> operator <attribute>*
- *<condition>* AND *<condition>*
- *<condition>* OR *<condition>*
- NOT *<condition>*

Selection Condition - Examples

- $\sigma_{Id>3000 \text{ OR } Hobby='hiking'}(\text{Person})$
- $\sigma_{Id>3000 \text{ AND } Id<3999}(\text{Person})$
- $\sigma_{\text{NOT}(Hobby='hiking')}(\text{Person})$
- $\sigma_{Hobby\neq'hiking'}(\text{Person})$

Project Operator

- Produces table containing subset of columns of argument table

$$\pi_{attribute\ list}(relation)$$

- Example:

Person

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
1123	John	123 Main	coins
5556	Mary	7 Lake Dr	hiking
9876	Bart	5 Pine St	stamps

$\pi_{Name,Hobby}$(Person)

Name	*Hobby*
John	stamps
John	coins
Mary	hiking
Bart	stamps

Project Operator

- Example:

Person

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
1123	John	123 Main	coins
5556	Mary	7 Lake Dr	hiking
9876	Bart	5 Pine St	stamps

$\pi_{Name,Address}$(Person)

Name	*Address*
John	123 Main
Mary	7 Lake Dr
Bart	5 Pine St

Result is a table (no duplicates); can have fewer tuples than the original

Expressions

$\pi_{Id, Name}(\sigma_{Hobby='stamps' \text{ OR } Hobby='coins'}(\text{Person}))$

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
1123	John	123 Main	coins
5556	Mary	7 Lake Dr	hiking
9876	Bart	5 Pine St	stamps

Person

Id	*Name*
1123	John
9876	Bart

Result

Set Operators

- Relation is a set of tuples, so set operations should apply: $\cap$, $\cup$, – (set difference)
- Result of combining two relations with a set operator is a relation => all its elements must be tuples having same structure
- Hence, scope of set operations limited to *union compatible relations*

Union Compatible Relations

- Two relations are *union compatible* if
  - Both have same number of columns
  - Names of attributes are the same in both
  - Attributes with the same name in both relations have the same domain
- Union compatible relations can be combined using *union*, *intersection*, and *set difference*

Example

Tables:

Person (*SSN, Name, Address, Hobby*)

Professor (*Id, Name, Office, Phone*)

are not union compatible.

But

π_{Name} (Person) and π_{Name} (Professor)

are union compatible so

π_{Name} (Person) - π_{Name} (Professor)

makes sense.

Cartesian Product

- If R and S are two relations, $R \times S$ is the set of all concatenated tuples $\langle x,y \rangle$, where x is a tuple in R and y is a tuple in S
  - R and S need not be union compatible
- $R \times S$ is expensive to compute:
  - Factor of two in the size of each row
  - Quadratic in the number of rows

A	*B*
x1	x2
x3	x4

R

C	*D*
y1	y2
y3	y4

S

A	*B*	*C*	*D*
x1	x2	y1	y2
x1	x2	y3	y4
x3	x4	y1	y2
x3	x4	y3	y4

$R \times S$

Renaming

- Result of expression evaluation is a relation
- Attributes of relation must have distinct names. This is not guaranteed with Cartesian product
  - e.g., suppose in previous example A and *C* have the same name
- Renaming operator tidies this up. To assign the names $A_1, A_2, \ldots A_n$ to the attributes of the n column relation produced by expression *expr* use

  expr $[A_1, A_2, \ldots A_n]$

Example

Transcript (*StudId, CrsCode, Semester, Grade*)

Teaching (*ProfId, CrsCode, Semester*)

$\pi_{StudId, CrsCode}$ (Transcript)[*StudId, CrsCode1*]

$\times$ $\pi_{ProfId, CrsCode}$(Teaching) [*ProfId, Crscode2*]

This is a relation with 4 attributes:

StudId, CrsCode1, ProfId, CrsCode2

Derived Operation: Join

A (*general* or *theta*) *join* of R and S is the expression

$R \bowtie_{join\text{-}condition} S$

where *join-condition* is a *conjunction* of terms:

A_i *oper* B_i

in which A_i is an attribute of R; B_i is an attribute of S; and *oper* is one of $=, <, >, \geq, \neq, \leq$.

The meaning is:

$\sigma_{join\text{-}condition'}(R \times S)$

where *join-condition* and *join-condition'* are the same, except for possible renamings of attributes (next)