Relational Algebra

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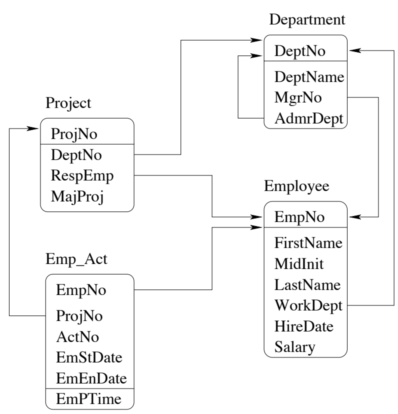
CS 640
Principles of Database Management and Use
Winter 2013

Notes

Database Schema Used in Examples



Notes

Relational Algebra

- the relational algebra consists of a set of *operators*
- relational algebra is *closed*
  - each operator takes as input zero or more relations
  - each operator defines a single output relation in terms of its input relation(s)
  - relational operators can be composed to form expressions that define new relations in terms of existing relations.
- *Notation*:
  R is a relation name; E is a relational algebra expression

Notes

Primary Relational Operators

- Relation Name: R
- Selection: $\sigma_{condition}(E)$
  - result schema is the same as E's
  - result instance includes the subset of the tuples of E that each satisfies the condition
- Projection: $\pi_{attributes}(E)$
  - result schema includes only the specified attributes
  - result instance could have as many tuples as E, except that duplicates are eliminated

Notes

Primary Relational Operators (cont'd)

- Rename: $\rho(R(\overline{F}), E)$
  - $\overline{F}$ is a list of terms of the form $oldname \rightarrow newname$
  - returns the result of E with columns renamed according to $\overline{F}$.
  - remembers the result as R for future expressions
- Product: $E_1 \times E_2$
  - result schema has all of the attributes of E_1 and all of the attributes of E_2
  - result instance includes one tuple for every pair of tuples (one from each expression result) in E_1 and E_2
  - sometimes called cross-product or Cartesian product
  - renaming is needed when E_1 and E_2 have common attributes

Notes

Cross Product Example

R

AAA	BBB
a_1	b_1
a_2	b_2
a_3	b_3

S

CCC	DDD
c_1	d_1
c_2	d_2

$R \times S$

AAA	BBB	CCC	DDD
a_1	b_1	c_1	d_1
a_2	b_2	c_1	d_1
a_3	b_3	c_1	d_1
a_1	b_1	c_2	d_2
a_2	b_2	c_2	d_2
a_3	b_3	c_2	d_2

Notes

Select,Project,Product Examples

- Note: Use *Emp* to mean the Employee relation, *Proj* the project relation
- Find the last names and hire dates of employees who make more than $100000.

$$\pi_{LastName,HireDate}(\sigma_{Salary>100000}(Emp))$$

- For each project for which department E21 is responsible, find the name of the employee in charge of that project.

$$\pi_{ProjNo,LastName}(\sigma_{DeptNo=E21}(\sigma_{RespEmp=EmpNo}(Emp \times Proj)))$$

Notes

Joins

- Conditional join: $E_1 \bowtie_{condition} E_2$
  - equivalent to $\sigma_{condition}(E_1 \times E_2)$
  - special case: *equijoin*

$$Proj \bowtie_{(\mathrm{RespEmp}=\mathrm{EmpNo})} Emp$$

- Natural join ($E_1 \bowtie E_2$)
  - The result of $E_1 \bowtie E_2$ can be formed by the following steps
    1. form the cross-product of E_1 and E_2 (renaming duplicate attributes)
    2. eliminate from the cross product any tuples that do not have matching values for *all pairs* of attributes common to schemas E_1 and E_2
    3. project out duplicate attributes
  - if no attributes in common, this is just a product

Notes

Example: Natural Join

- Consider the natural join of the Project and Department tables, which have attribute DeptNo in common
  - the schema of the result will include attributes ProjName, DeptNo, RespEmp, MajProj, DeptName, MgrNo, and AdmrDept
  - the resulting relation will include one tuple for each tuple in the Project relation (why?)

Notes

Set-Based Relational Operators

- Union ($R \cup S$):
  - schemas of R and S must be "union compatible"
  - result includes all tuples that appear either in R or in S or in both
- Difference ($R - S$):
  - schemas of R and S must be "union compatible"
  - result includes all tuples that appear in R and that do not appear in S
- Intersection ($R \cap S$):
  - schemas of R and S must be "union compatible"
  - result includes all tuples that appear in both R and S
- Union Compatible:
  - Same number of fields.
  - 'Corresponding' fields have the same type

Notes

Relational Division

X

A	B	C
a_1	b_1	c_1
a_1	b_1	c_2
a_1	b_2	c_2
a_2	b_1	c_1
a_2	b_1	c_2
a_2	b_2	c_2
a_2	b_3	c_3
a_3	b_1	c_1

S

B	C
b_1	c_1
b_1	c_2
b_2	c_2

X/S

A
a_1
a_2

Notes

Division is the Inverse of Product

R

A
a_1
a_2

S

B	C
b_1	c_1
b_1	c_2
b_2	c_2

$R \times S$

A	B	C
a_1	b_1	c_1
a_1	b_1	c_2
a_1	b_2	c_2
a_2	b_1	c_1
a_2	b_1	c_2
a_2	b_2	c_2

$(R \times S)/S$

A
a_1
a_2

Notes

Summary of Relational Operators

$$
\begin{array}{rcl}
E & ::= & R \\
 & | & \sigma_{condition}(E) \\
 & | & \pi_{attributes}(E) \\
 & | & \rho(R(\overline{F}), E) \\
 & | & E_1 \times E_2 \\
 & | & E_1 \bowtie_{condition} E_2 \\
 & | & E_1 \bowtie E_2 \\
 & | & E_1 \cup E_2 \\
 & | & E_1 \cap E_2 \\
 & | & E_1 - E_2 \\
 & | & E_1 \,/\, E_2
\end{array}
$$

Notes

Algebraic Equivalences

- This:

$$\pi_{ProjNo,LastName}(\sigma_{DeptNo=E21}(\sigma_{RespEmp=EmpNo}(E \times P)))$$

- is equivalent to this:

$$\pi_{ProjNo,LastName}(\sigma_{DeptNo=E21}(E \bowtie_{RespEmp=EmpNo} P))$$

- is equivalent to this:

$$\pi_{ProjNo,LastName}(E \bowtie_{RespEmp=EmpNo} \sigma_{DeptNo=E21}(P))$$

- is equivalent to this:

$$
\begin{array}{ll}
\pi_{ProjNo,LastName}(& (\quad \pi_{LastName,EmpNo}(E)) \bowtie_{RespEmp=EmpNo} \\
 & (\quad \pi_{ProjNo,RespEmp}(\sigma_{DeptNo=E21}(P))))
\end{array}
$$

Notes

Relational Completeness

Definition (Relationally Complete)

A query language that is at least as expressive as relational algebra is said to be *relationally complete*.

Languages that are relationally complete:

- Relational Algebra
- Query by Example (QBE)
- SQL
  - SQL has additional expressive power because it captures duplicate tuples, unknown values, aggregation, ordering, ...
- etc.

Notes

Discussion Next Week

Topic: SQL (SEQUEL2) and QBE

Read:

- D.D. Chamberlin et al.: **SEQUEL 2: A Unified Approach to Data Definition, Manipulation, and Control**. *IBM Journal of Research and Development 20*(6): 560-575 (1976).
- M.M. Zloof: **Query-by-Example: A Data Base Language**. *IBM Systems Journal 16*(4): 324-343 (1977).

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