Database II

Lecture 5

Relational Algebra II

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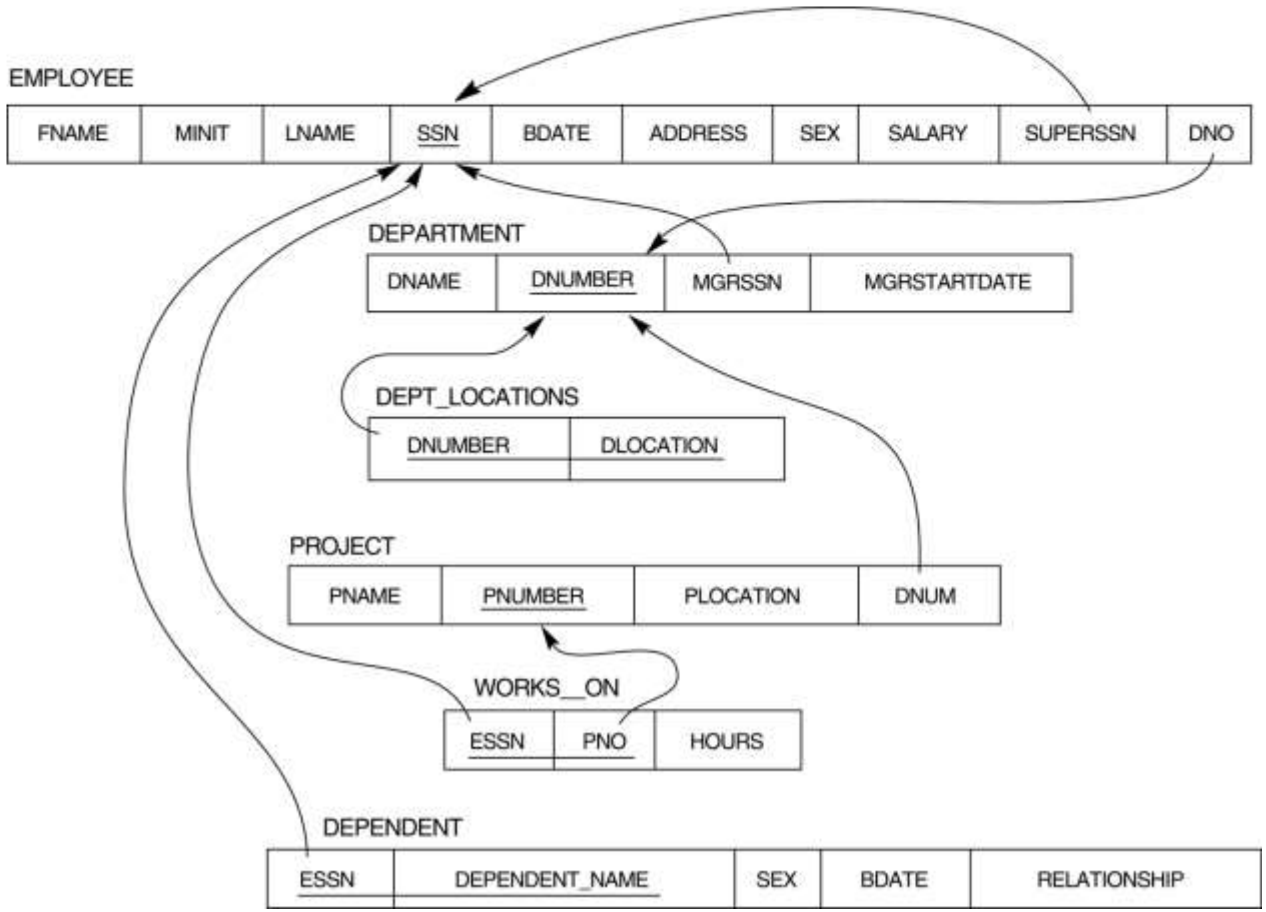
Lecture Outline

- Example Database Application (COMPANY)
- Relational Algebra
  - Join Operations
  - Additional Algebra Operations

Database State for COMPANY

All examples discussed below refer to the COMPANY database shown here.



The query results in this lecture refer to this database state

Figure 5.6
One possible database state for the COMPANY relational database schema.

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

WORKS_ON

Essn	Pno	Hours
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0
333445555	3	10.0
333445555	10	10.0
333445555	20	10.0
999887777	30	30.0
999887777	10	10.0
987987987	10	35.0
987987987	30	5.0
987654321	30	20.0
987654321	20	15.0
888665555	20	NULL

PROJECT

Pname	Pnumber	Plocation	Dnum
ProductX	1	Bellaire	5
ProductY	2	Sugarland	5
ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship
333445555	Alice	F	1986-04-05	Daughter
333445555	Theodore	M	1983-10-25	Son
333445555	Joy	F	1958-05-03	Spouse
987654321	Abner	M	1942-02-28	Spouse
123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

Binary Relational Operations

- **JOIN Operation**
  – The sequence of cartesian product followed by select is used quite commonly to identify and select related tuples from two relations, a special operation, called **JOIN**. It is denoted by a $\bowtie$
  – This operation is very important for any relational database with more than a single relation, because it allows us to process relationships among relations.
  – The general form of a join operation on two relations $R(A_1, A_2, \ldots, A_n)$ and $S(B_1, B_2, \ldots, B_m)$ is:

    $R \bowtie_{\text{<join condition>}} S$

    where R and S can be any relations that result from general *relational algebra expressions.*

Binary Relational Operations (cont.)

Example: Suppose that we want to retrieve the name of the manager of each department. To get the manager's name, we need to combine each DEPARTMENT tuple with the EMPLOYEE tuple whose SSN value matches the MGRSSN value in the department tuple. We do this by using the join $\bowtie$ operation.

$$\textbf{DEPT\_MGR} \leftarrow \textbf{DEPARTMENT} \bowtie_{\textbf{MGRSSN=SSN}} \textbf{EMPLOYEE}$$

DEPT_MGR

Dname	Dnumber	Mgr_ssn	. . .	Fname	Minit	Lname	Ssn	. . .
Research	5	333445555	. . .	Franklin	T	Wong	333445555	. . .
Administration	4	987654321	. . .	Jennifer	S	Wallace	987654321	. . .
Headquarters	1	888665555	. . .	James	E	Borg	888665555	. . .

Figure 6.6
Result of the JOIN operation

Binary Relational Operations (cont.)

- **EQUI-JOIN Operation**

  The most common use of join involves join conditions with equality comparisons only. Such a join, where the only comparison operator used is =, is called an EQUIJOIN. In the result of an EQUIJOIN we always have one or more pairs of attributes (whose names need not be identical) that have *identical values* in every tuple.

  The JOIN seen in the previous example was EQUIJOIN.

- **NATURAL JOIN Operation**

  Because one of each pair of attributes with identical values is superfluous, a new operation called natural join—denoted by *—was created to get rid of the second (superfluous) attribute in an EQUIJOIN condition.

  The standard definition of natural join requires that the two join attributes, or each pair of corresponding join attributes, have the **same name** in both relations. If this is not the case, a renaming operation is applied first.

Example of NATURAL JOIN operation

Example: To apply a natural join on the DNUMBER attributes of DEPARTMENT and DEPT_LOCATIONS, it is sufficient to write:

DEPT_LOCS ← DEPARTMENT * DEPT_LOCATIONS

(a)

PROJ_DEPT

Pname	Pnumber	Plocation	Dnum	Dname	Mgr_ssn	Mgr_start_date
ProductX	1	Bellaire	5	Research	333445555	1988-05-22
ProductY	2	Sugarland	5	Research	333445555	1988-05-22
ProductZ	3	Houston	5	Research	333445555	1988-05-22
Computerization	10	Stafford	4	Administration	987654321	1995-01-01
Reorganization	20	Houston	1	Headquarters	888665555	1981-06-19
Newbenefits	30	Stafford	4	Administration	987654321	1995-01-01

(b)

DEPT_LOCS

Dname	Dnumber	Mgr_ssn	Mgr_start_date	Location
Headquarters	1	888665555	1981-06-19	Houston
Administration	4	987654321	1995-01-01	Stafford
Research	5	333445555	1988-05-22	Bellaire
Research	5	333445555	1988-05-22	Sugarland
Research	5	333445555	1988-05-22	Houston

Figure 6.7
Results of two NATURAL JOIN operations.
(a) PROJ_DEPT ← PROJECT * DEPT.
(b) DEPT_LOCS ← DEPARTMENT * DEPT_LOCATIONS.

Theta-Join Operation

- Theta-Join
  - Notation: $R = R_1 \bowtie_{\theta} R_2$
  - Meaning: is equivalent to $R = \sigma_C (R_1 \times R_2)$
- Here θ can be any condition
  - θ can be $<$ $>$ $=$ $\neq$ $\leq$ $\geq$
  - If equal (=), then it is an EQUI-JOIN

Theta-Join Operation: Example

- Relation r, s : r

A	B	C	D
α	1	α	a
β	2	γ	a
γ	4	β	b
α	1	γ	a
δ	2	β	b

s

B	D	E
1	a	α
3	a	β
1	a	γ
2	b	δ
3	b	ε

- $r \bowtie_{r.B > s.B} s$:

A	B	C	D	B2	D2	E
β	2	γ	a	1	a	α
β	2	γ	a	1	a	γ
γ	4	β	b	1	a	α
γ	4	β	b	3	a	β
γ	4	β	b	1	a	γ
γ	4	β	b	2	b	δ
γ	4	β	b	3	b	ε
δ	2	β	b	1	a	α
δ	2	β	b	1	a	γ

Rq: $r \bowtie_{r.B > s.B} s = \sigma_{B>B2}((r) \times (\rho_{B2, D2, E}(s)))$

Recap of Relational Algebra Operations

Table 6.1
Operations of Relational Algebra

Operation	Purpose	Notation
SELECT	Selects all tuples that satisfy the selection condition from a relation R.	$\sigma_{<\text{selection condition}>}(R)$
PROJECT	Produces a new relation with only some of the attributes of R, and removes duplicate tuples.	$\pi_{<\text{attribute list}>}(R)$
THETA JOIN	Produces all combinations of tuples from R_1 and R_2 that satisfy the join condition.	$R_1 \bowtie_{<\text{join condition}>} R_2$
EQUIJOIN	Produces all the combinations of tuples from R_1 and R_2 that satisfy a join condition with only equality comparisons.	$R_1 \bowtie_{<\text{join condition}>} R_2$, OR $R_1 \bowtie_{(<\text{join attributes 1}>),\ (<\text{join attributes 2}>)} R_2$
NATURAL JOIN	Same as EQUIJOIN except that the join attributes of R_2 are not included in the resulting relation; if the join attributes have the same names, they do not have to be specified at all.	$R_1 *_{<\text{join condition}>} R_2$, OR $R_1 *_{(<\text{join attributes 1}>),\ (<\text{join attributes 2}>)} R_2$ OR $R_1 * R_2$
UNION	Produces a relation that includes all the tuples in R_1 or R_2 or both R_1 and R_2; R_1 and R_2 must be union compatible.	$R_1 \cup R_2$
INTERSECTION	Produces a relation that includes all the tuples in both R_1 and R_2; R_1 and R_2 must be union compatible.	$R_1 \cap R_2$
DIFFERENCE	Produces a relation that includes all the tuples in R_1 that are not in R_2; R_1 and R_2 must be union compatible.	$R_1 - R_2$
CARTESIAN PRODUCT	Produces a relation that has the attributes of R_1 and R_2 and includes as tuples all possible combinations of tuples from R_1 and R_2.	$R_1 \times R_2$
DIVISION	Produces a relation $R(X)$ that includes all tuples $t[X]$ in $R_1(Z)$ that appear in R_1 in combination with every tuple from $R_2(Y)$, where $Z = X \cup Y$.	$R_1(Z) \div R_2(Y)$

Additional Relational Operations

- **Aggregate Functions and Grouping**
  - A type of request that cannot be expressed in the basic relational algebra is to specify mathematical **aggregate functions** on collections of values from the database.
  - Examples of such functions include retrieving the average or total salary of all employees or the total number of employee tuples. These functions are used in simple statistical queries that summarize information from the database tuples.
  - Common functions applied to collections of numeric values include SUM, AVERAGE, MAXIMUM, and MINIMUM. The COUNT function is used for counting tuples or values.

Aggregate Function Operation

- Use of the Aggregate Functional operation $\mathcal{F}$
  - $\mathscr{F}_{\text{MAX Salary}}$ (EMPLOYEE) retrieves the maximum salary value from the EMPLOYEE relation
  - $\mathscr{F}_{\text{MIN Salary}}$ (EMPLOYEE) retrieves the minimum Salary value from the EMPLOYEE relation
  - $\mathscr{F}_{\text{SUM Salary}}$ (EMPLOYEE) retrieves the sum of the Salary from the EMPLOYEE relation
  - $\mathscr{F}_{\text{COUNT SSN, AVERAGE Salary}}$ (EMPLOYEE) computes the count (number) of employees and their average salary
    - Note: count just counts the number of rows, without removing duplicates

Using Grouping with Aggregation

- The previous examples all summarized one or more attributes for a set of tuples
  - Maximum Salary or Count (number of) Ssn
- Grouping can be combined with Aggregate Functions
- Example: For each department, retrieve the DNO, COUNT SSN, and AVERAGE SALARY
- A variation of aggregate operation $\mathcal{F}$ allows this:
  - Grouping attribute placed to left of symbol
  - Aggregate functions to right of symbol
  - ${}_{\text{DNO}}\ \mathcal{F}_{\text{COUNT SSN, AVERAGE Salary}}$ (EMPLOYEE)
- Above operation groups employees by DNO (department number) and computes the count of employees and average salary per department

Additional Relational Operations (cont.)

Figure 6.10
The aggregate function operation.
(a) $\rho_{R(\text{Dno, No\_of\_employees, Average\_sal})}(_{\text{Dno}}\,\Im\,_{\text{COUNT Ssn, AVERAGE Salary}}(\text{EMPLOYEE}))$.
(b) $_{\text{Dno}}\,\Im\,_{\text{COUNT Ssn, AVERAGE Salary}}(\text{EMPLOYEE})$.
(c) $\Im\,_{\text{COUNT Ssn, AVERAGE Salary}}(\text{EMPLOYEE})$.

(a) **R**

Dno	No_of_employees	Average_sal
5	4	33250
4	3	31000
1	1	55000

(b)

Dno	Count_ssn	Average_salary
5	4	33250
4	3	31000
1	1	55000

(c)

Count_ssn	Average_salary
8	35125

Additional Relational Operations (cont.)

- **The OUTER JOIN Operation**
  - In NATURAL JOIN tuples without a *matching* (or *related*) tuple are eliminated from the join result. Tuples with null in the join attributes are also eliminated. This amounts to loss of information.
  - A set of operations, called outer joins, can be used when we want to keep all the tuples in R, or all those in S, or all those in both relations in the result of the join, regardless of whether or not they have matching tuples in the other relation.
  - The left outer join operation keeps every tuple in the *first* or *left* relation R in R ⟕ S; if no matching tuple is found in S, then the attributes of S in the join result are filled or "padded" with null values.
  - A similar operation, right outer join, keeps every tuple in the *second* or right relation S in the result of R ⟖ S.
  - A third operation, full outer join, denoted by ⟗ keeps all tuples in both the left and the right relations when no matching tuples are found, padding them with null values as needed.

Additional Relational Operations (cont.)

RESULT	FNAME	MINIT	LNAME	DNAME
	John	B	Smith	null
	Franklin	T	Wong	Research
	Alicia	J	Zelaya	null
	Jennifer	S	Wallace	Administration
	Ramesh	K	Narayan	null
	Joyce	A	English	null
	Ahmad	V	Jabbar	null
	James	E	Borg	Headquarters

Examples of Queries in Relational Algebra

- **Q1: Retrieve the name and address of all employees who work for the 'Research' department.**

RESEARCH_DEPT ← σ DNAME='Research' (DEPARTMENT)

RESEARCH_EMPS ← (RESEARCH_DEPT $\bowtie$ DNUMBER= DNOEMPLOYEE EMPLOYEE)

RESULT ← π FNAME, LNAME, ADDRESS (RESEARCH_EMPS)

- **Q6: Retrieve the names of employees who have no dependents.**

ALL_EMPS ← π SSN(EMPLOYEE)

EMPS_WITH_DEPS(SSN) ← π ESSN(DEPENDENT)

EMPS_WITHOUT_DEPS ← (ALL_EMPS - EMPS_WITH_DEPS)

RESULT ← π LNAME, FNAME (EMPS_WITHOUT_DEPS * EMPLOYEE)