Lesson 6: Relational Algebra

CSC430/530 – DATABASE MANAGEMENT SYSTEMS

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OUTLINE

- Introduction.
- Unary relational operations.
  - SELECT, PROJECT, RENAME.
- Set theory relational operations.
  - UNION, INTERSECTION, SET DIFFERENCE, CARTESIAN PRODUCT.
- Binary relational operations.
  - JOIN, DIVISION.
- Additional relational operations.
  - Aggregation and grouping.

INTRODUCTION

- Why relational algebra?
  - Formal foundation for **relational** model **operations**.
  - Basis of **query implementation** and **optimization**.
  - Many concepts are incorporated in **SQL**.
- Relational algebra defines the basic **set of operations** for the relational data model.
  - Operations allow user to specify basic **retrieval** request.
    - Result of such a retrieval query is a **new relation**.
    - New relation can be further manipulated using same operations, forming **relational algebra expression**.

UNARY RELATIONAL OPERATIONS: SELECT (1)

- Selects a **subset** of the tuples from a relation based on a **selection condition**.
  - Denoted by σ (*sigma*).
  - Acts as a **filter** – keeps only those tuples that **satisfy** the selection condition.

- $\sigma_{\text{<selection condition>}}(R)$
  - Selection condition – **Boolean expression** on attributes of relation R.
    - *<attribute name><comparison op><constant value>* or *<attribute name><comparison op><attribute name>*

- **Examples**:
  - *Retrieve the EMPLOYEE tuples whose department number is 4:*

    $\sigma_{\text{Dno} = 4}(\text{EMPLOYEE})$
  - *Retrieve the EMPLOYEE tuples whose salary is greater than $30,000:*

    $\sigma_{\text{Salary} > 30000}(\text{EMPLOYEE})$

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

UNARY RELATIONAL OPERATIONS: SELECT (2)

- **Properties**:
  - Operation produces new relation that has **same attributes** as R.
  - The number of **tuples** in resulting relation is always **less than** (or equal to) the number of tuples in R.
  - Operation is **commutative**.
    - $\sigma_{<cond1>}(\sigma_{<cond2>}(R)) = \sigma_{<cond2>}(\sigma_{<cond1>}(R))$
  - Can be **cascaded** into single operation.
    - $\sigma_{<cond1>}(\sigma_{<cond2>}(\sigma_{<cond3>}(R))) = \sigma_{<cond1> \text{ AND } <cond2> \text{ AND } <cond3>}(R)$

UNARY RELATIONAL OPERATIONS: SELECT (3)

- **Example**: *Retrieve employees who either work in department 4 and make over $25,000 per year or work in department 5 and make over $30,000.*
  - $\sigma_{(Dno = 4 \text{ AND } Salary > 25000) \text{ OR } (Dno = 5 \text{ AND } Salary > 30000)}(EMPLOYEE)$

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

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
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

UNARY RELATIONAL OPERATIONS: PROJECT (1)

- Keeps certain **columns** (*attributes*) from a relation and **discards** the other columns.
  - Only the **list of specified** columns (*attributes*) is kept in each tuple.
  - Denoted by π (pi).

- $\pi_{<\text{attribute list}>}(R)$
  - Attribute list – **desired list** of attributes from relation R.

- **Example**:
  - *List each employee's first name, last name, and salary.*

$$\pi_{\text{Lname, Fname, Salary}}(\text{EMPLOYEE})$$

- Removes any **duplicate** tuples.
  - Because the result of operation is a new **relation** (*set of tuples*).

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
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Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
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James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

UNARY RELATIONAL OPERATIONS: PROJECT (2)

- **Properties**:
  - The number of **tuples** in the resulting relation is **less than** or equal to the number of tuples in R.
    - **Equals** only when the list of attributes includes a **key** of R.
  - Operation is not (*generally*) **commutative**.
    - $\pi_{\text{<list1>}}(\pi_{\text{<list2>}}(R)) = \pi_{\text{<list1>}}(R)$, only if <list2> contains the **same attributes** as in <list1>.

UNARY RELATIONAL OPERATIONS: PROJECT (3)

- **Examples**:
  - π Lname, Fname, Salary (EMPLOYEE)

Lname	Fname	Salary
Smith	John	30000
Wong	Franklin	40000
Zelaya	Alicia	25000
Wallace	Jennifer	43000
Narayan	Ramesh	38000
English	Joyce	25000
Jabbar	Ahmad	25000
Borg	James	55000

  - π Sex, Salary (EMPLOYEE)

Sex	Salary
M	30000
M	40000
F	25000
F	43000
M	38000
M	25000
M	55000

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
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James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

UNARY RELATIONAL OPERATIONS: RENAME (1)

- Relational operations can be **nested** to an arbitrary depth.
  - *Retrieve first name, last name and salary of employees who work for department 5.*
  - $\pi_{\text{Fname, Lname, Salary}}(\sigma_{\text{Dno = 5}}(\text{EMPLOYEE}))$
- Alternatively, same operation can be **rewritten** by the **sequence** of operation, giving **names** to intermediate relations.
  - $\text{DEP5\_EMPS} \leftarrow \sigma_{\text{Dno = 5}}(\text{EMPLOYEE})$

    $\text{RESULT} \leftarrow \pi_{\text{Fname, Lname, Salary}}(\text{DEP5\_EMPS})$
- **Attributes names** can also be **renamed** if needed.
  - $\text{TEMP} \leftarrow \sigma_{\text{Dno = 5}}(\text{EMPLOYEE})$

    $\text{R(First\_name, Last\_name, Salary)} \leftarrow \pi_{\text{Fname, Lname, Salary}}(\text{TEMP})$

UNARY RELATIONAL OPERATIONS: RENAME (2)

- General **RENAME** operation ρ (*rho*) can be expressed by any of the following forms:
  - $\rho_{S(B1, B2, \ldots, Bn)}(R)$ changes both:
    - the relation name to S, and
    - the column (attribute) names to B_1, B_2, …, B_n.
  - $\rho_{S}(R)$ changes:
    - the relation name only, to S.
  - $\rho_{(B1, B2, \ldots, Bn)}(R)$ changes:
    - the column (attribute) names only, to B_1, B_2, …, B_n.

UNARY RELATIONAL OPERATIONS: RENAME (3)

- **Example**: *Retrieve first name, last name and salary of employees who work for department 5.*
  - $\pi_{\text{Fname, Lname, Salary}}(\sigma_{\text{Dno=5}}(\text{EMPLOYEE}))$

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

Fname	Lname	Salary
John	Smith	30000
Franklin	Wong	40000
Ramesh	Narayan	38000
Joyce	English	25000

- $\text{TEMP} \leftarrow \sigma_{\text{Dno = 5}}(\text{EMPLOYEE})$

  $\text{R(First\_name, Last\_name, Salary)} \leftarrow \pi_{\text{Fname, Lname, Salary}}(\text{TEMP})$

TEMP

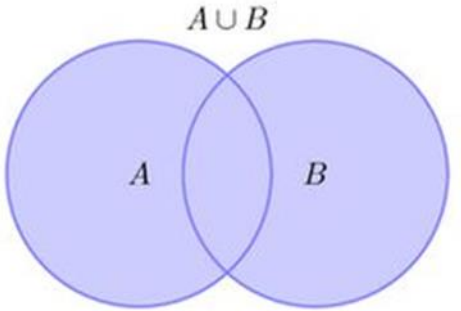
Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston,TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston,TX	M	40000	888665555	5
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble,TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5

R

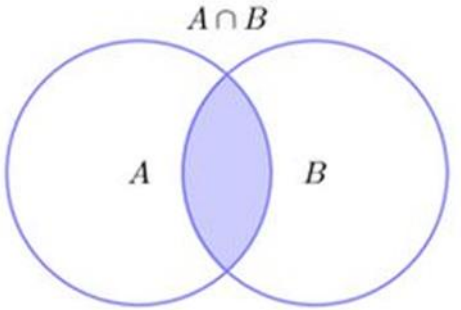
First_name	Last_name	Salary
John	Smith	30000
Franklin	Wong	40000
Ramesh	Narayan	38000
Joyce	English	25000

UNION, INTERSECTION & SET DIFFERENCE (1)

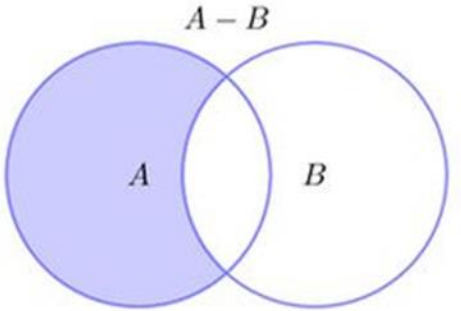
- **Union** operation - A ∪ B.
  - The result is a **relation** that includes all tuples that are **either** in **A or** in **B or** in **both**.
  - **Duplicate** tuples are **eliminated**.



- **Intersection** operation - A ∩ B.
  - The result is a **relation** that includes all tuples that are in **both A** and **B**.
  - The **attribute names** in the result will be the **same** as the attribute names in A.



- **Set difference** operation - A – B.
  - The result is a **relation** that includes all tuples that are in **A** but **not** in **B**.
  - The **attribute names** in the result will be the **same** as the attribute names in A.



- The two operand relations A and B must be **type compatible**.
  - **Same number** of attributes.
  - **Pair** of **attributes** must be from **same** (*compatible*) **domain**.

UNION, INTERSECTION & SET DIFFERENCE (2)

- **Examples**:
  - (a) Two compatible relations.
  - (b) STUDENT ∪ INSTRUCTOR.
  - (c) STUDENT ∩ INSTRUCTOR.
  - (d) STUDENT – INSTRUCTOR.
  - (e) INSTRUCTOR – STUDENT.

(a) STUDENT

Fn	Ln
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Ernest	Gilbert

INSTRUCTOR

Fname	Lname
John	Smith
Ricardo	Browne
Susan	Yao
Francis	Johnson
Ramesh	Shah

(b)

Fn	Ln
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Ernest	Gilbert
John	Smith
Ricardo	Browne
Francis	Johnson

(c)

Fn	Ln
Susan	Yao
Ramesh	Shah

(d)

Fn	Ln
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Ernest	Gilbert

(e)

Fname	Lname
John	Smith
Ricardo	Browne
Francis	Johnson

UNION, INTERSECTION & SET DIFFERENCE (3)

- **Properties**:
  - **Union** & **intersection** are **commutative**.
    - $A \cup B = B \cup A$, and $A \cap B = B \cap A$
  - **Union** & **intersection** are **associative** and can be treated as **n-ary** operations.
    - $A \cup (B \cup C) = (A \cup B) \cup C$
    - $(A \cap B) \cap C = A \cap (B \cap C)$
  - **Set difference** is NOT **commutative**.
    - $A - B \neq B - A$

CARTESIAN PRODUCT (1)

- Used to **combine tuples** from two relations in a **combinatorial** fashion.
  - $R(A_1, A_2, \ldots, A_n) \times S(B_1, B_2, \ldots, B_m)$
- Results in a **relation Q** with *n + m* **attributes**.
  - $Q(A_1, A_2, \ldots, A_n, B_1, B_2, \ldots, B_m)$, in that order.
- **State** of **relation Q** has one tuple for each **combination** of tuples – one from **R** and one from **S**.

CARTESIAN PRODUCT (2)

- Generally, the result of **Cartesian product** is not **meaningful**.
  - It only becomes meaningful when **followed** by other **operations**.

- **Example**: *List names of female employees and their dependents.*
  - FEMALE_EMPS ← $\sigma_{Sex = 'F'}$ (EMPLOYEE)

    EMPNAMES ← $\pi_{Fname, Lname, Ssn}$ (FEMALE_EMPS)

    EMP_DEPENDENTS ← EMPNAMES x DEPENDENT

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

FEMALE_EMPS

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
Alicia	J	Zelaya	999887777	1968-07-19	3321Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291Berry, Bellaire, TX	F	43000	888665555	4
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5

EMPNAMES

Fname	Lname	Ssn
Alicia	Zelaya	999887777
Jennifer	Wallace	987654321
Joyce	English	453453453

CARTESIAN PRODUCT (3)

- Generally, the result of **Cartesian product** is not **meaningful**.
  - It only becomes meaningful when **followed** by other **operations**.

- **Example**: *List names of female employees and their dependents.*
  - FEMALE_EMPS $\leftarrow \sigma_{Sex = 'F'}$ (EMPLOYEE)

    EMPNAMES $\leftarrow \pi_{Fname, Lname, Ssn}$ (FEMALE_EMPS)

    EMP_DEPENDENTS $\leftarrow$ EMPNAMES x DEPENDENT

EMP_DEPENDENTS

Fname	Lname	Ssn	Essn	Dependent_name	Sex	Bdate	...
Alicia	Zelaya	999887777	333445555	Alice	F	1986-04-05	...
Alicia	Zelaya	999887777	333445555	Theodore	M	1983-10-25	...
Alicia	Zelaya	999887777	333445555	Joy	F	1958-05-03	...
Alicia	Zelaya	999887777	987654321	Abner	M	1942-02-28	...
Alicia	Zelaya	999887777	123456789	Michael	M	1988-01-04	...
Alicia	Zelaya	999887777	123456789	Alice	F	1988-12-30	...
Alicia	Zelaya	999887777	123456789	Elizabeth	F	1967-05-05	...
Jennifer	Wallace	987654321	333445555	Alice	F	1986-04-05	...
Jennifer	Wallace	987654321	333445555	Theodore	M	1983-10-25	...
Jennifer	Wallace	987654321	333445555	Joy	F	1958-05-03	...
Jennifer	Wallace	987654321	987654321	Abner	M	1942-02-28	...
Jennifer	Wallace	987654321	123456789	Michael	M	1988-01-04	...
Jennifer	Wallace	987654321	123456789	Alice	F	1988-12-30	...
Jennifer	Wallace	987654321	123456789	Elizabeth	F	1967-05-05	...
Joyce	English	453453453	333445555	Alice	F	1986-04-05	...
Joyce	English	453453453	333445555	Theodore	M	1983-10-25	...
Joyce	English	453453453	333445555	Joy	F	1958-05-03	...
Joyce	English	453453453	987654321	Abner	M	1942-02-28	...
Joyce	English	453453453	123456789	Michael	M	1988-01-04	...
Joyce	English	453453453	123456789	Alice	F	1988-12-30	...
Joyce	English	453453453	123456789	Elizabeth	F	1967-05-05	...

CARTESIAN PRODUCT (4)

- Generally, the result of **Cartesian product** is not **meaningful**.
  - It only becomes meaningful when **followed** by other **operations**.

- **Example**: *List names of female employees and their dependents.*
  - FEMALE_EMPS $\leftarrow \sigma_{Sex = 'F'}$ (EMPLOYEE)

    EMPNAMES $\leftarrow \pi_{Fname, Lname, Ssn}$ (FEMALE_EMPS)

    EMP_DEPENDENTS $\leftarrow$ EMPNAMES x DEPENDENT
  - To make it meaningful, we can add **Select** and **Project** operations.

    ACTUAL_DEPS $\leftarrow \sigma_{Ssn = Essn}$ (EMP_DEPENDENTS)

    RESULT $\leftarrow \pi_{Fname, Lname, Dependent\_name}$ (ACTUAL_DEPS)

ACTUAL_DEPENDENTS

Fname	Lname	Ssn	Essn	Dependent_name	Sex	Bdate	...
Jennifer	Wallace	987654321	987654321	Abner	M	1942-02-28	...

RESULT

Fname	Lname	Dependent_name
Jennifer	Wallace	Abner

EMP_DEPENDENTS

Fname	Lname	Ssn	Essn	Dependent_name	Sex	Bdate	...
Alicia	Zelaya	999887777	333445555	Alice	F	1986-04-05	...
Alicia	Zelaya	999887777	333445555	Theodore	M	1983-10-25	...
Alicia	Zelaya	999887777	333445555	Joy	F	1958-05-03	...
Alicia	Zelaya	999887777	987654321	Abner	M	1942-02-28	...
Alicia	Zelaya	999887777	123456789	Michael	M	1988-01-04	...
Alicia	Zelaya	999887777	123456789	Alice	F	1988-12-30	...
Alicia	Zelaya	999887777	123456789	Elizabeth	F	1967-05-05	...
Jennifer	Wallace	987654321	333445555	Alice	F	1986-04-05	...
Jennifer	Wallace	987654321	333445555	Theodore	M	1983-10-25	...
Jennifer	Wallace	987654321	333445555	Joy	F	1958-05-03	...
Jennifer	Wallace	987654321	987654321	Abner	M	1942-02-28	...
Jennifer	Wallace	987654321	123456789	Michael	M	1988-01-04	...
Jennifer	Wallace	987654321	123456789	Alice	F	1988-12-30	...
Jennifer	Wallace	987654321	123456789	Elizabeth	F	1967-05-05	...
Joyce	English	453453453	333445555	Alice	F	1986-04-05	...
Joyce	English	453453453	333445555	Theodore	M	1983-10-25	...
Joyce	English	453453453	333445555	Joy	F	1958-05-03	...
Joyce	English	453453453	987654321	Abner	M	1942-02-28	...
Joyce	English	453453453	123456789	Michael	M	1988-01-04	...
Joyce	English	453453453	123456789	Alice	F	1988-12-30	...
Joyce	English	453453453	123456789	Elizabeth	F	1967-05-05	...

BINARY RELATIONAL OPERATIONS: JOIN (1)

- Combines **related** tuples from two relations into **single** "longer" **tuple**.
  - Allows processing **relationships** among relations.
  - Denoted by ⋈
- $R \bowtie_{\text{<join condition>}} S$
  - Join condition is specified on **attributes** from two relations and is **evaluated** for **each combination** of tuples.
  - If condition is True then the combination is included in the resulting relation as a **single combined tuple**.
- Each **join condition** has a general form $A_i \, \Theta \, B_j$, where
  - A_i is an attribute of R.
  - B_j is an attribute of S.
  - Θ (theta) is one of the comparisons operators (=, >, ≥, <, ≤, ≠).

BINARY RELATIONAL OPERATIONS: JOIN (2)

- **Example**: *List department managers.*
  - DEPT_MGR ← DEPARTMENT ⋈ $_{\text{Mgr\_ssn = Ssn}}$ EMPLOYEE

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_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	...

BINARY RELATIONAL OPERATIONS: JOIN (3)

- **Special cases** of Join operation:
  - **EQUIJOIN**.
    - Only **"="** comparison operator is used.
    - Most **common** use of JOIN operation.
    - Results in one or more pairs of attributes that have **identical values** in every tuple.
  - **NATURAL JOIN**.
    - **Removes** second (*superfluous*) attribute in EQUIOIN.
    - Two **join attributes** must have the same **name** in both relations.
      - A **renaming** operation might be applied first.
    - Denoted by ***.**

BINARY RELATIONAL OPERATIONS: JOIN (4)

- **Examples**: *List departments' locations.*
  - DEPT_LOCS ← DEPARTMENT * DEPT_LOCATIONS

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

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

BINARY RELATIONAL OPERATIONS: JOIN (4)

- **Examples**: *List projects' departments.*
  - PROJ_DEPT ← PROJECT * $\rho_{(Dname, Dnum, Mgr\_ssn, Mgr\_strat\_date)}$ (DEPARTMENT)

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

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

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

COMPLETE SET OF RELATIONAL OPERATIONS

- The set of operations $\{\sigma, \pi, \cup, -, \rho, x\}$ is called a **complete set**.
  - Any other relational algebra expression can be **expressed** by a **combination** of these operations.
- **Examples:**
  - $R \cap S = (R \cup S) - ((R - S) \cup (S - R))$
  - $R \bowtie_{\text{<join condition>}} S = \sigma_{\text{<join condition>}} (R \times S)$

BINARY RELATIONAL OPERATIONS: DIVISION

- Denoted by ÷ and applied to two relations $R(Z) \div S(X) = T(Y)$.
  - **Attributes** of *S* are a **subset** of the **attributes** of *R*.
  - Tuples in *S* **restrict** *R* by selecting those tuples that **match** all values present S.

- **Example**:
  - *Retrieve the names of employees who work on all the projects that John Smith works on.*
    - $SMITH \leftarrow \sigma_{Fname = 'John" \text{ AND } Lname = 'Smith'} (EMPLOYEE)$

      $SMITH\_PNOS \leftarrow \pi_{Pno} (WORKS\_ON \bowtie_{Essn = Ssn} SMITH)$

      $SSN\_PNOS \leftarrow \pi_{Essn, Pno} (WORKS\_ON)$

      $SSNS(Ssn) \leftarrow SSN\_PNOS \div SMITH\_PNOS$

      $RESULT \leftarrow \pi_{Fname, Lname} (SSNS * EMPLOYEE)$

SMITH_PNOS

Pno
1
2

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

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

BINARY RELATIONAL OPERATIONS: DIVISION

- Denoted by ÷ and applied to two relations $R(Z) \div S(X) = T(Y)$.
  - **Attributes** of *S* are a **subset** of the **attributes** of *R*.
  - Tuples in *S* **restrict** *R* by selecting those tuples that **match** all values present S.
- **Example**:
  - *Retrieve the names of employees who work on all the projects that John Smith works on.*
    - SMITH $\leftarrow \sigma_{\text{Fname = 'John" AND Lname = 'Smith'}}$ (EMPLOYEE)

      SMITH_PNOS $\leftarrow \pi_{\text{Pno}}$ (WORKS_ON $\bowtie_{\text{Essn = Ssn}}$ SMITH)

      SSN_PNOS $\leftarrow \pi_{\text{Essn, Pno}}$ (WORKS_ON)

      SSNS(Ssn) $\leftarrow$ SSN_PNOS ÷ SMITH_PNOS

      RESULT $\leftarrow \pi_{\text{Fname, Lname}}$ (SSNS * EMPLOYEE)

SSN_PNOS

Essn	Pno
123456789	1
123456789	2
666884444	3
453453453	1
453453453	2
333445555	2
333445555	3
333445555	10
333445555	20
999887777	30
999887777	10
987987987	10
987987987	30
987654321	30
987654321	20
888665555	20

SMITH_PNOS

Pno
1
2

SSNS

Ssn
123456789
453453453

SUMMARY OF RELATIONAL OPERATIONS (1)

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 $R_1 \bowtie_{\text{(<join attributes 1>), (<join attributes 2>)}} R_2$
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 $R_1 *_{\text{(<join attributes 1>), (<join attributes 2>)}} R_2$ OR $R_1 * R_2$

SUMMARY OF RELATIONAL OPERATIONS (2)

OPERATION	PURPOSE	NOTATION
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 $Z = X \cup Y$.	$R_1(Z) \div R_2(Y)$

AGGREGATION & GROUPING (1)

- Specifying simple **mathematical aggregate** functions on collections of values from the database cannot be **directly expressed** in the **basic** relational algebra.
  - For example - get **average** or **total** salary of all employees or the **total number** of employee tuples.
    - **SUM**, **AVERAGE**, **MAXIMUM**, **MINIMUM**, **COUNT**.
- **Grouping operation and aggregate functions** are used for this purpose.
  - <grouping attributes> $\Im$ <function list> (R)
    - Grouping attributes - list of **attributes** of the relation R.
    - Function list - list of (*<function>* *<attribute>*) pairs.

AGGREGATION & GROUPING (2)

- **Example**: *Retrieve each department number, the number of employees in the department, and their average salary.*
  - $\rho_{R(Dno,\ No\_of\_employees,\ Average\_sal)}(Dno\ \Im\ COUNT\ Ssn,\ AVERAGE\ Salary\ (EMPLOYEE))$

R

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

  - $Dno\ \Im\ COUNT\ Ssn,\ AVERAGE\ Salary\ (EMPLOYEE)$

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

  - $\Im\ COUNT\ Ssn,\ AVERAGE\ Salary\ (EMPLOYEE)$

Count_ssn	Average_salary
8	35125

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

SUMMARY

- Unary operations.
  - Select, project, rename.
- Set theory operations.
  - Union, intersection, set difference, Cartesian product.
- Binary operations.
  - Joins, division.
- Additional relational operations.
  - Aggregation, grouping.

EXAMPLES OF QUERIES

- **Query 1.**
  - Retrieve the name and address of all employees who work for the ‘Research’ department.

$$RESEARCH\_DEPT \leftarrow \sigma_{Dname='Research'}(DEPARTMENT)$$
$$RESEARCH\_EMPS \leftarrow (RESEARCH\_DEPT \bowtie_{Dnumber=Dno} EMPLOYEE)$$
$$RESULT \leftarrow \pi_{Fname,\ Lname,\ Address}(RESEARCH\_EMPS)$$

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

EXAMPLES OF QUERIES

- **Query 1.**
  - Retrieve the name and address of all employees who work for the 'Research' department.

$$\text{RESEARCH\_DEPT} \leftarrow \sigma_{\text{Dname='Research'}}(\text{DEPARTMENT})$$
$$\text{RESEARCH\_EMPS} \leftarrow (\text{RESEARCH\_DEPT} \bowtie_{\text{Dnumber=Dno}} \text{EMPLOYEE})$$
$$\text{RESULT} \leftarrow \pi_{\text{Fname, Lname, Address}}(\text{RESEARCH\_EMPS})$$

  - Single in-line version:

$$\pi_{\text{Fname, Lname, Address}} (\sigma_{\text{Dname='Research'}}(\text{DEPARTMENT} \bowtie_{\text{Dnumber=Dno}} (\text{EMPLOYEE}))$$

  - **Note:** This query could be specified in other ways. For example, the order of the JOIN and SELECT operations could be reversed, or the JOIN could be replaced by a NATURAL JOIN after renaming one of the join attributes to match the other join attribute name.

EXAMPLES OF QUERIES

- **Query 2.**
  - For every project located in ‘Stafford’, list the project number, the controlling department number, and the department manager’s last name, address, and birth date.

$$\text{STAFFORD\_PROJS} \leftarrow \sigma_{\text{Plocation}=\text{'Stafford'}}(\text{PROJECT})$$
$$\text{CONTR\_DEPTS} \leftarrow (\text{STAFFORD\_PROJS} \bowtie_{\text{Dnum}=\text{Dnumber}} \text{DEPARTMENT})$$
$$\text{PROJ\_DEPT\_MGRS} \leftarrow (\text{CONTR\_DEPTS} \bowtie_{\text{Mgr\_ssn}=\text{SsnE}} \text{MPLOYEE})$$
$$\text{RESULT} \leftarrow \pi_{\text{Pnumber, Dnum, Lname, Address, Bdate}}(\text{PROJ\_DEPT\_MGRS})$$

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

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

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

EXAMPLES OF QUERIES

- **Query 2.**
  - For every project located in ‘Stafford’, list the project number, the controlling department number, and the department manager’s last name, address, and birth date.

$$\text{STAFFORD\_PROJS} \leftarrow \sigma_{\text{Plocation='Stafford'}}(\text{PROJECT})$$
$$\text{CONTR\_DEPTS} \leftarrow (\text{STAFFORD\_PROJS} \bowtie_{\text{Dnum=Dnumber}} \text{DEPARTMENT})$$
$$\text{PROJ\_DEPT\_MGRS} \leftarrow (\text{CONTR\_DEPTS} \bowtie_{\text{Mgr\_ssn=SsnE}} \text{MPLOYEE})$$
$$\text{RESULT} \leftarrow \pi_{\text{Pnumber, Dnum, Lname, Address, Bdate}}(\text{PROJ\_DEPT\_MGRS})$$

  - **Note:** In this example, we first select the projects located in Stafford, then join them with their controlling departments, and then join the result with the department managers. Finally, we apply a project operation on the desired attributes.

EXAMPLES OF QUERIES

- **Query 3.**
  - Find the names of employees who work on all the projects controlled by department number 5.

$$DEPT5\_PROJS \leftarrow \rho_{(Pno)}(\pi_{Pnumber}(\sigma_{Dnum=5}(PROJECT)))$$
$$EMP\_PROJ \leftarrow \rho_{(Ssn,\ Pno)}(\pi_{Essn,\ Pno}(WORKS\_ON))$$
$$RESULT\_EMP\_SSNS \leftarrow EMP\_PROJ \div DEPT5\_PROJS$$
$$RESULT \leftarrow \pi_{Lname,\ Fname}(RESULT\_EMP\_SSNS * EMPLOYEE)$$

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

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

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

EXAMPLES OF QUERIES

- **Query 3.**
  - Find the names of employees who work on all the projects controlled by department number 5.

$$\text{DEPT5\_PROJS} \leftarrow \rho_{(\text{Pno})}(\pi_{\text{Pnumber}}(\sigma_{\text{Dnum}=5}(\text{PROJECT})))$$
$$\text{EMP\_PROJ} \leftarrow \rho_{(\text{Ssn, Pno})}(\pi_{\text{Essn, Pno}}(\text{WORKS\_ON}))$$
$$\text{RESULT\_EMP\_SSNS} \leftarrow \text{EMP\_PROJ} \div \text{DEPT5\_PROJS}$$
$$\text{RESULT} \leftarrow \pi_{\text{Lname, Fname}}(\text{RESULT\_EMP\_SSNS} * \text{EMPLOYEE})$$

  - **Note:** In this query, we first create a table DEPT5_PROJS that contains the project numbers of all projects controlled by department 5. Then we create a table EMP_PROJ that holds (Ssn, Pno) tuples, and apply the division operation. Notice that we renamed the attributes so that they will be correctly used in the division operation. Finally, we join the result of the division, which holds only Ssn values, with the EMPLOYEE table to retrieve the Fname, Lname attributes from EMPLOYEE.

EXAMPLES OF QUERIES

- **Query 4.**
  - Make a list of project numbers for projects that involve an employee whose last name is ‘Smith’, either as a worker or as a manager of the department that controls the project.

$$SMITHS(Essn) \leftarrow \pi_{Ssn}\,(\sigma_{Lname='Smith'}(EMPLOYEE))$$
$$SMITH\_WORKER\_PROJS \leftarrow \pi_{Pno}(WORKS\_ON * SMITHS)$$
$$MGRS \leftarrow \pi_{Lname,\ Dnumber}(EMPLOYEE \bowtie_{Ssn=Mgr\_ssn} DEPARTMENT)$$
$$SMITH\_MANAGED\_DEPTS(Dnum) \leftarrow \pi_{Dnumber}\,(\sigma_{Lname='Smith'}(MGRS))$$
$$SMITH\_MGR\_PROJS(Pno) \leftarrow \pi_{Pnumber}(SMITH\_MANAGED\_DEPTS * PROJECT)$$
$$RESULT \leftarrow (SMITH\_WORKER\_PROJS \cup SMITH\_MGR\_PROJS)$$

  - **Note:** In this query, we retrieved the project numbers for projects that involve an employee named Smith as a worker in SMITH_WORKER_PROJS. Then we retrieved the project numbers for projects that involve an employee named Smith as manager of the department that controls the project in SMITH_MGR_PROJS. Finally, we applied the UNION operation on SMITH_WORKER_PROJS and SMITH_MGR_PROJS.

EXAMPLES OF QUERIES

- **Query 5.**
  - List the names of all employees with more than two dependents.

$$T1(\text{Ssn, No\_of\_dependents}) \leftarrow \text{Essn}\ \Im\ \text{COUNT Dependent\_name}(\text{DEPENDENT})$$
$$T2 \leftarrow \sigma_{\text{No\_of\_dependents}>2}(T1)$$
$$\text{RESULT} \leftarrow \pi_{\text{Lname, Fname}}(T2 * \text{EMPLOYEE})$$

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

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

EXAMPLES OF QUERIES

- **Query 5.**
  - List the names of all employees with more than two dependents.

$$T1(\text{Ssn, No\_of\_dependents}) \leftarrow {}_{\text{Essn}}\Im_{\text{COUNT Dependent\_name}}(\text{DEPENDENT})$$
$$T2 \leftarrow \sigma_{\text{No\_of\_dependents}>2}(T1)$$
$$\text{RESULT} \leftarrow \pi_{\text{Lname, Fname}}(T2 * \text{EMPLOYEE})$$

  - **Note:** For this query, we have to use the AGGREGATE FUNCTION operation with the COUNT aggregate function. We assume that dependents of the same employee have distinct Dependent_name values.

EXAMPLES OF QUERIES

- **Query 6.**
  - Retrieve the names of employees who have no dependents.

$$ALL\_EMPS \leftarrow \pi_{Ssn}(EMPLOYEE)$$
$$EMPS\_WITH\_DEPS(Ssn) \leftarrow \pi_{Essn}(DEPENDENT)$$
$$EMPS\_WITHOUT\_DEPS \leftarrow (ALL\_EMPS - EMPS\_WITH\_DEPS)$$
$$RESULT \leftarrow \pi_{Lname,\ Fname}(EMPS\_WITHOUT\_DEPS * EMPLOYEE)$$

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

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

EXAMPLES OF QUERIES

- **Query 6.**
  - Retrieve the names of employees who have no dependents.

$$ALL\_EMPS \leftarrow \pi_{Ssn}(EMPLOYEE)$$
$$EMPS\_WITH\_DEPS(Ssn) \leftarrow \pi_{Essn}(DEPENDENT)$$
$$EMPS\_WITHOUT\_DEPS \leftarrow (ALL\_EMPS - EMPS\_WITH\_DEPS)$$
$$RESULT \leftarrow \pi_{Lname,\ Fname}(EMPS\_WITHOUT\_DEPS * EMPLOYEE)$$

  - **Note:** We first retrieve a relation with all employee Ssns in ALL_EMPS. Then we create a table with the Ssns of employees who have at least one dependent in EMPS_WITH_DEPS. Then we apply the SET DIFFERENCE operation to retrieve employees Ssns with no dependents in EMPS_WITHOUT_DEPS, and finally join this with EMPLOYEE to retrieve the desired attributes.

EXAMPLES OF QUERIES

- **Query 7.**
  - List the names of managers who have at least one dependent.

$$MGRS(Ssn) \leftarrow \pi_{Mgr\_ssn}(DEPARTMENT)$$
$$EMPS\_WITH\_DEPS(Ssn) \leftarrow \pi_{Essn}(DEPENDENT)$$
$$MGRS\_WITH\_DEPS \leftarrow (MGRS \cap EMPS\_WITH\_DEPS)$$
$$RESULT \leftarrow \pi_{Lname,\ Fname}(MGRS\_WITH\_DEPS * EMPLOYEE)$$

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

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

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

EXAMPLES OF QUERIES

- **Query 7.**
  - List the names of managers who have at least one dependent.

$$\text{MGRS}(\text{Ssn}) \leftarrow \pi_{\text{Mgr\_ssn}}(\text{DEPARTMENT})$$
$$\text{EMPS\_WITH\_DEPS}(\text{Ssn}) \leftarrow \pi_{\text{Essn}}(\text{DEPENDENT})$$
$$\text{MGRS\_WITH\_DEPS} \leftarrow (\text{MGRS} \cap \text{EMPS\_WITH\_DEPS})$$
$$\text{RESULT} \leftarrow \pi_{\text{Lname, Fname}}(\text{MGRS\_WITH\_DEPS} * \text{EMPLOYEE})$$

  - **Note:** In this query, we retrieve the Ssns of managers in MGRS, and the Ssns of employees with at least one dependent in EMPS_WITH_DEPS, then we apply the SET INTERSECTION operation to get the Ssns of managers who have at least one dependent.