Relational Algebra

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Operations on Relational Model

- Definition
- Updates
  - Insert
  - Delete
  - Modify
- Retrievals
  - Relational algebra

Define Relational Databases

DECLARE SCHEMA COMPANY;
DECLARE DOMAIN PERSON_SSNS **TYPE** FIXED_CHAR (9);
DECLARE DOMAIN PERSON_NAMES **TYPE** VARIABLE_CHAR(15);
DECLARE DOMAIN PERSON_INITIALS **TYPE** ALPHABETIC_CHAR(1);
DECLARE DOMAIN DATES **TYPE** DATE;
DECLARE DOMAIN ADDRESSES **TYPE** VARIABLE_CHAR(35);
DECLARE DOMAIN PERSON_SEX **TYPE** ENUMERATED {M, F};
DECLARE DOMAIN PERSON_SALARIES **TYPE** MONEY;
DECLARE DOMAIN DEPT_NUMBERS **TYPE** INTEGER_RANGE [1,10];
DECLARE DOMAIN DEPT_NAMES **TYPE** VARIABLE_CHAR(20);

Define a Relation

DECLARE RELATION EMPLOYEE
FOR SCHEMA COMPANY
ATTRIBUTES

FNAME	**DOMAIN** PERSON_NAMES,
MINIT	**DOMAIN** PERSON_INITIALS,
LNAME	**DOMAIN** PERSON_NAMES,
SSN	**DOMAIN** PRESON_SSNS,
BDATE	**DOMAIN** DATES,
ADDRESS	**DOMAIN** ADDRESSES,
SEX	**DOMAIN** PERSON_SEX,
SALARY	**DOMAIN** PERSON_SALARIES,
SUPERSSN	**DOMAIN** PERSON_SSNS,
DNO	**DOMAIN** DEPT_NUMBERS

CONSTRAINTS PRIMARY_KEY (SSN),
FOREIGN_KEY (SUPERSSN) **REFERENCES** EMPLOYEE,
FOREIGN_KEY (DNO) **REFERENCES** DEPARTMENT;

Define another Relation

DECLARE RELATION DEPARTMENT
FOR SCHEMA COMPANY
ATTRIBUTES

DNAME	**DOMAIN** DEPT_NAMES,
DNUMBER	**DOMAIN** DEPT_NUMBERS,
MGRSSN	**DOMAIN** PRESON_SSNS,
MGRSTARTDTAE	**DOMAIN** DATES

CONSTRAINTS PRIMARY_KEY (DNUMBER),
KEY (DNAME),
FOREIGN_KEY (MGRSSN) **REFERENCES** EMPLOYEE;

The COMPANY Relational Database Schema

EMPLOYEE

FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO

DEPARTMENT

DNAME	DNUMBER	MGRSSN	MGRSTARTDATE

DEPT_LOCATIONS

DNUMBER	DLOCATION

WORKS_ON

ESSN	PNO	HOURS

PROJECT

PNAME	PNUMBER	PLOCATION	DNUM

DEPENDENT

ESSN	DEPENDENT_NAME	SEX	BDATE	RELATIONSHIP

A Relational Database Instance of the COMPANY Schema

EMPLOYEE	FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO
	John	B	Smith	123456789	09-JAN-55	731 Fondren, Houston, TX	M	30000	333445555	5
	Franklin	T	Wong	333445555	08-DEC-45	638 Voss, Houston, TX	M	40000	888665555	5
	Alicia	J	Zelaya	999887777	19-JUL-58	3321 Castle, Spring, TX	F	25000	987654321	4
	Jennifer	S	Wallace	987654321	20-JUN-31	291 Berry, Bellaire, TX	F	43000	888665555	4
	Ramesh	K	Narayan	666884444	15-SEP-52	975 Fire Oak, Humble, TX	M	38000	333445555	5
	Joyce	A	English	453453453	31-JUL-62	5631 Rice, Houston, TX	F	25000	333445555	5
	Ahmad	V	Jabbar	987987987	29-MAR-59	980 Dallas, Houstom TX	M	25000	987654321	4
	James	E	Borg	888665555	10-NOV-27	450 Stone, Houston, TS	M	55000	null	1

A Relational Database Instance of the COMPANY Schema (Continued)

DEPT_LOCATIONS	DNUMBER	DLOCATION
	1	Houston
	4	Stafford
	5	Bellaire
	5	Sugarland
	5	Houston

DEPARTMENT	DNAME	DNUMBER	MGRSSN	MGRSTARTDATE
	Research	5	333445555	22-MAY-78
	Administration	4	987654321	01-JAN-85
	Headquarters	1	888665555	19-JUN-71

A Relational Database Instance of the COMPANY Schema (Continued)

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

A Relational Database Instance of the COMPANY Schema (Continued)

DEPENDENT	ESSN	DEPENDENT_NAME	SEX	BDATE	RELATIONSHIP
	333445555	Alics	F	05-APR076	DAUGHTER
	333445555	Theodore	M	25-OCT-73	SON
	333445555	Joy	F	03-MAY-48	SPOUSE
	987654321	Abner	M	29-FEB-32	SPOUSE
	123456789	Michael	M	01-JAN-78	SON
	123456789	Alice	F	31-DEC-78	DAUGHTER
	123456789	Elizabeth	F	05-MAY-57	SPOUSE

Insert

- Insert <'Cecilia', 'F', 'Kolonsky', '677678989', '05-Apr-50', '6357 Windy Lane, Katy, TX', F, 28000, null, 4> into EMPLOYEE
- Insert <'Alicia', 'J', 'Zelaya', '999887777', '05-Apr-50', '6357 Windy Lane, Katy, TX', F, 28000, '987654321', 4> into EMPLOYEE
  - violate the key constraint
- Insert <'Cecilia', 'F', 'Kolonsky', null, '05-Apr-50', '6357 Windy Lane, Katy, TX', F, 28000, null, 4> into EMPLOYEE
  - violate the entity integrity

Delete

- Can violate only referential integrity
- Delete the WORKS_ON tuple with PNO=10 and ESSN='999887777'
- Delete the EMPLOY tuple with SSN='999887777'
  - violate the referential integrity
  - reject the delete
  - cascade the deletion
  - modify the referencing attribute

Modify

- Modifying an attribute which is neither a primary key nor foreign key causes no problems
- Modifying a primary key value is similar to deleting one tuple and inserting another
- Modifying a foreign key may violate referential integrity

Operations of Relation Algebra

- Set operations
  - Union
  - Intersection
  - Difference
  - Product
- Born original operations
  - Select
  - Project
  - Join
  - Aggregate function

RESULT ← RESULT1 ∪ RESULT2

RESULT1	SSN
	123456789
	333445555
	666884444
	453453453

RESULT2	SSN
	333445555
	888665555

RESULT	SSN
	123456789
	333445555
	666884444
	453453453
	888665555

UNION, INTERSECTION, and DIFFERENCE

(a) Two union compatible relations.

STUDENT	FN	LN
	Susan	Yao
	Ramesh	Shah
	Johnny	Kohler
	Barbara	Jones
	Amy	Ford
	Jimmy	Wand
	Emest	Gilbert

INSTRUCTOR	FNAME	LNAME
	John	Smith
	Ricardo	Browne
	Susan	Yao
	Francis	Johnson
	Ramesh	Shah

UNION, INTERSECTION, and DIFFERENCE (Continued)

(b) STUDENT ∪ INSTRUCTOR

FN	LN
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Emest	Gilbert
John	Smith
Ricardo	Browne
Francis	Johnson

(c) STUDENT ∩ INSTRUCTOR

FN	LN
Susan	Yao
Ramesh	Shah

UNION, INTERSECTION, and DIFFERENCE (Continued)

(d) STUDENT − INSTRUCTOR

FN	LN
Jonny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Emest	Gilbert

(e) INSTRUCTOR − STUDENT

FNAME	LNAME
John	Smith
Ricardo	Browne
Francis	Johnson

CARTESIAN PRODUCT

FEMALE_EMPS	FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO
	Alicia	J	Zelaya	999887777	19-JUL-58	3321 Castle, Spring, TX	F	25000	987654321	4
	Jennifer	S	Wallace	987654321	20-JUN-31	291 Berry, Bellaire, TX	F	43000	888665555	4
	Joyce	A	English	453453453	31-JUL-62	5631 Rice, Houston, TX	F	25000	333445555	5

EMPNAMES	FNAME	LNAME	SSN
	Alicia	Zelaya	999887777
	Jennifer	Wallace	987654321
	Joyce	English	453453453

RESULT	FNAME	LNAME	DEPENDENT_NAME
	Jennifer	Wallace	Abner

ACTUAL_DEPENDENTS	FNAME	LNAME	SSN	ESSN	DEPENDENT_NAME	SEX	BDATE
	Jennifer	Wallace	987654321	987654321	Abner	M	29-FEB-32

CARTESIAN PRODUCT (Continued)

EMP_DEPENDENTS	FNAME	LNAME	SSN	ESSN	DEPENDENT_NAME	SEX	BDATE	. . .
	Alicia	Zelaya	999887777	33344555	Alice	F	05-APR-76	. . .
	Alicia	Zelaya	999887777	33344555	Theodore	M	25-OCT-73	. . .
	Alicia	Zelaya	999887777	33344555	Joy	F	03-MAY-48	. . .
	Alicia	Zelaya	999887777	987654321	Abner	M	29-FEB-32	. . .
	Alicia	Zelaya	999887777	123456789	Michael	M	01-JAN-78	. . .
	Alicia	Zelaya	999887777	123456789	Alice	F	31-DEC-78	. . .
	Alicia	Zelaya	999887777	123456789	Elizabeth	F	05-MAY-57	. . .
	Jennifer	Wallace	987654321	333445555	Alice	F	05-APR-76	. . .
	Jennifer	Wallace	987654321	333445555	Theodore	M	25-OCT-73	. . .
	Jennifer	Wallace	987654321	333445555	Joy	F	03-MAY-48	. . .
	Jennifer	Wallace	987654321	987654321	Abner	M	29-FEB-32	. . .
	Jennifer	Wallace	987654321	123456789	Michael	M	01-JAN-78	. . .
	Jennifer	Wallace	987654321	123456789	Alice	F	31-DEC-78	. . .
	Jennifer	Wallace	987654321	123456789	Elizabeth	F	05-MAY-57	. . .
	Joyce	English	453453453	333445555	Alice	F	05-APR-76	. . .
	Joyce	English	453453453	333445555	Theodore	M	25-OCT-73	. . .
	Joyce	English	453453453	333445555	Joy	F	03-MAY-48	. . .
	Joyce	English	453453453	987654321	Abner	M	29-FEB-32	. . .
	Joyce	English	453453453	123456789	Michael	M	01-JAN-78	. . .
	Joyce	English	453453453	123456789	Alice	F	31-DEC-78	. . .
	Joyce	English	543453453	123456789	Elizabeth	F	05-MAY-57	. . .

The DIVISION Operation

SSN_PNOS	ESSN	PNO
	123456789	1
	123456789	2
	666884444	3
	453453453	1
	453453453	2
	453453453	3
	333445555	4
	333445555	10
	333445555	20
	999887777	30
	999887777	10
	987987987	10
	987987987	30
	987654321	30
	987654321	20
	888665555	20

Dividing SSN_PNOS by SMITH_PNOS.

SSNS(SSN)← SSN_PNOS ÷SMITH_PNOS

SMITH_PNOS	PNO
	1
	2

SSNS	SSN
	123456789
	453453453

The DIVISION Operation (Continued)

R	A	B
	a1	b1
	a2	b1
	a3	b1
	a4	b1
	a1	b2
	a3	b2
	a2	b3
	a3	b3
	a4	b3
	a1	b4
	a2	b4
	a3	b4

(b) T←R÷ S

S	A
	a1
	a2
	a3

T	B
	b1
	b4

The DIVISION Operation (Continued)

- T=R÷S
- Assume Y=att[R]-att[S]
- $T_1=\Pi_Y R$
- $T_2=\Pi_Y(S \times T_1-R)$
- $T=T_1 - T_2$

SELECT

- use to select a subset of the tuples in a relation that satisfy a selection condition
- σ <selection condition><Table>
- <selection> is made up of a number of clauses
  - <attribute name> <comparison op> <constant value>
  - <attribute name> <comparison op > <attribute name>
- The fraction of tuples selected by a selection condition is referred to as the selectivity of the condition

PROJECT

- PROJECT extracts certain columns from the table and discards the other columns
- PROJECT is used to “project” attributes we are interested in
- π <attribute list> (<relation name>)
- The resulting relation has only the attributes specified in <attribute list> and in the same order as they appear in the list
- The degree equals to the number of attributes in <attribute list>
- Duplicate elimination

SELECT and PROJECT Operations

(a) $\sigma_{(DNO=4\ AND\ SALARY>25000)\ OR\ (DNO=5\ AND\ SALARY>30000)}$ (EMPLOYEE)

FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO
Franklin	T	Wong	333445555	08-DEC-45	638 Voss, Houston, TX	M	40000	888665555	5
Jennifer	S	Wallace	987654321	20-JUN031	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	15-SEP-52	975 FireOak, Humble, TX	M	38000	333445555	5

(b) $\pi_{LNAME, FNAME, SALARY}$ (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

(c) $\pi_{SEX, SALARY}$ (EMPLOYEE)

SEX	SALARY
M	30000
M	40000
F	25000
F	43000
M	38000
M	25000
M	55000

Renaming of Attributes

- $\pi_{LNAME, FNAME, SALARY}(\sigma_{DNO=5}$ (EMPLOYEE))
- DEP5_EMPS $\leftarrow \sigma_{DNO=5}$ (EMPLOYEE)
- RESULT $\leftarrow \pi_{LNAME, FNAME, SALARY}$(DEP5_EMPS)
- R(LASTNAME, FIRSTNAME, SALARY) $\leftarrow$ $\pi_{LNAME, FNAME, SALARY}$(DEP5_EMPS)

Results of Relational Algebra

(a) $\pi_{LNAME, FNAME, SALARY}(\sigma_{DNO=5}$ (EMPLOYEE))

FNAME	LNAME	SALARY
John	Smith	30000
Franklin	Wong	40000
Ramesh	Narayan	38000
Joyce	Engilsh	25000

Results of Relational Algebra (Continued)

(b) The same expression using intermediate relations and renaming of attributes.

TEMP	FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO
	John	B	Smith	123456789	09-JAN-55	731 Fondren, Houston, TX	M	30000	333445555	5
	Franklin	T	Wong	333445555	08-DEC-45	638 Voss, Houston, TX	M	40000	888665555	5
	Ramesh	K	Narayan	666884444	15-SEP-52	975 Fire Oak, Humble, TX	M	38000	333445555	5
	Joyce	A	English	453453453	31-JUL-62	5631 Rice, Houston, TX	F	25000	333445555	5

R	FIRSTNAME	LASTNAME	SALARY
	John	Smith	30000
	Franklin	Wong	40000
	Ramesh	Narayan	38000
	Joyce	English	25000

The JOIN Operation

- JOIN denoted by $\bowtie$ is used to combine related tuples from two relations into single tuples

DEPT_MGR $\leftarrow$ DEPARTMENT $\bowtie_{MGRSSN=SSN}$ EMPLOYEE

RESULT $\leftarrow \pi_{DNAME, LNAME, FNAME}$ (DEPT_MGR)

DEPT_MGR	DNAME	DNUMBER	MGRSSN	, , ,	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	. . .

JOIN

- THETA JOIN
  - comparison operators can be {=, <, >, >=, <=, !=}
- EQUIJOIN
  - the allowed comparison is "="
- NATURAL JOIN
  - EQUIJOIN followed by deleting superfluous attributes
- CROSS JOIN: CARTESIAN PRODUCT
  - no <join condition> is specified

The NATURAL JOIN operation

(a) PROJ_DEPT ← PROJECT * DEPT

PROJ_DEPT	PNAME	PNUMBER	PLOCATION	DNUM	DNAME	MGRSSN	MGRSTARTDATE
	ProductX	1	Bellaire	5	Research	333445555	22-MAY-78
	ProductY	2	Sugarland	5	Research	333445555	22-MAY-78
	ProductZ	3	Houston	4	Rsearch	333445555	22-MAY-78
	Computerization	10	Stafford	4	Administration	987654321	01-JAN-85
	Reorganization	20	Houston	1	Headquarters	888665555	19-JUN-71
	Newbenefits	30	Stafford	4	Administration	987654321	01-JAN-85

(b) DEPT_LOCS ← DEPARTMENT * DEPT_LOCATIONS

DEPT_LOCS	DNAME	DNUMBER	MGRSSN	MGRSTARTDATE	LOCATION
	Headquarters	1	888665555	19-JUN-71	Houston
	Administration	4	987654321	01-JAN-95	Stafford
	Research	5	333445555	22-MAY-78	Bellaire
	Research	5	333445555	22-MAY-78	Sugarland
	Research	5	333445555	22-MAY-78	Houston

Aggregate Functions

- Specify mathematical aggregate functions on sets of values from the database
  - e.g. group employee tuples by DNO, and then calculate the average salary of this group
  - SUM, AVERAGE, MAXIMUM, MINIMUM, COUNT

<grouping attributes> ℑ <function list> (<relation name>)

- R(DNO, NUMBER_OF_EMPLOYEES, AVERAGE_SAL) ← DNO ℑ COUNT SSN, AVERAGE SALARY(EMPLOY)

The FUNCTION Operation

(a) R (DNO,NO_OF_EMPLOYEES,AVERAGE_SAL) ← DNO ℑ COUNT SSN, AVERAGE SALARY (EMPLOYEE).

R	DNO	NO_OF_EMPLOYEES	AVERAGE_SAL
	5	4	33250
	4	3	31000
	1	1	55000

(b) DNO ℑ COUNT SSN, AVERAGE SALARY (EMPLOYEE).

DNO	COUNT_SSN	AVERAGE_SALARY
5	4	33250
4	3	31000
1	1	55000

(c) ℑ COUNT SSN, AVERAGE SALARY (EMPLOYEE).

COUNT_SSN	AVERAGE_SALARY
8	35125

Two-Level Recursion

(Borg's SSN is 88866555) (SSN) (SUPERSSN)

SUPERVISION	SSN1	SSN2
	123456789	333445555
	333445555	888665555
	999887777	987654321
	987654321	888665555
	666884444	333445555
	453453453	333445555
	987987987	987654321
	888665555	null

(Supervised by Borg)

RESULT1	SSN
	333445555
	987654321

(Supervised by Borg's subordinates)

RESULT2	SSN
	123456789
	999887777
	666884444
	453453453
	987987987

(RESULT1∪ RESULT 2)

RESULT	SSN
	123456789
	999887777
	666884444
	453453453
	987987987
	333445555
	987654321

The LEFT OUTER JOIN operation

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

OUTER UNION

- STUDENT(Name, SSN, Department, Advisor)
- FACULTY(Name, SSN, Department, Rank)
- RESULT(Name, SSN, Department, Advisor, Rank) ← STUDENT <OUTER UNION> FACULTY

Example QUERY 1

Retrieve the name and address of all employees who work for the 'Research' department.

$RESEARCH\_DEPT \leftarrow \sigma_{DNAME='Research'}(DEPARTMENT)$
$RESEARCH\_DEPT\_EMPS \leftarrow (RESEARCH\_DEPT \bowtie_{DNUMBER=DNO} EMPLOYEE)$
$RESULT \leftarrow \pi_{FNAME, LNAME, ADDRESS}(RESEARCH\_DEPT\_EMPS)$

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.

Example 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 birthdate.

$STAFFORD\_PROJS \leftarrow \sigma_{PLOCATION='Stafford}(PROJECT)$
$CONTR\_DEPT \leftarrow (STAFFORD\_PROJS \bowtie_{DNUM=DNUMBER} DEPARTMENT)$
$PROJ\_DEPT\_MGR \leftarrow (CONTR\_DEPT \bowtie_{MGRSSN=SSN} EMPLOYEE)$
$RESULT \leftarrow \pi_{PNUMBER, DNUM, LNAME, ADDRESS, BDATE}(PROJ\_DEPT\_MGR)$

Example QUERY 3

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

$DEPT5\_PROJS(PNO) \leftarrow \pi_{PNUMBER}(\sigma_{DNUM=5}(PROJECT))$
$EMP\_PROJ(SSN, PNO) \leftarrow \pi_{SSN, PNO}(WORKS\_ON)$
$RESULT\_ENP\_SSNS \leftarrow EMP\_PROJ \div DEPT5\_PROJS$
$RESULT \leftarrow \pi_{LNAME, FNAME}(RESULT\_EMP\_SSNS * EMPLOYEE)$

Example 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.

$SMITHS(ESSN) \leftarrow \pi_{SSN}(\sigma_{LNAME='Smith'}(EMPLOYEE))$
$SMITH\_WORKER\_PROJS \leftarrow \pi_{PNO}(WORKS\_ON * SMITH)$
$MGRS \leftarrow \pi_{LNAME, DNUMBER}(EMPLOYEE \bowtie_{SSN=MGRSSN} DEPARTMENT)$
$SMITH\_MGRS \leftarrow \sigma_{LNAME='Smith'}(MGRS)$
$SMITH\_MANAGED\_DEPTS(DNUM) \leftarrow \pi_{DNUMBER}(SMITH\_MGRS)$
$SMITH\_MGR\_PROJS(PNO) \leftarrow \pi_{PNUMBER}(SMITH\_MANAGED\_DEPTS * PROJECT)$
$RESULT \leftarrow (SMITH\_WORKER\_PROJS \cup SMITH\_MGR\_PROJS)$

Example QUERY 5

- Retrieve the names of employees who have no dependents.

$ALL\_EMPS \leftarrow \pi_{SSN}(EMPLOYEE)$
$EMP\_WITH\_DEPS(SSN) \leftarrow \pi_{ESSN}(DEPENDENT)$
$EMPS\_WITHOUT\_DEPS \leftarrow (ALL\_EMPS - EMPS\_WITH\_DEPS)$
$RESULT \leftarrow \pi_{LNAME, FNAME}(EMPS\_WITHOUT\_DEPS * EMPLOYEE)$

Example QUERY 6

- Find the names of managers who have at least one dependent.

MGR (SSN) ← π_{MGRSSN} (DEPARTMENT)
EMP_WITH_DEPS (SSN) ← π_{ESSN} (DEPENDENT)
MGRS_WITH_DEPS ← (MGRS $\cap$ EMPS_WITH_DEPS)
RESULT← $\pi_{LNAME, FNAME}$ (MGRS_WITH_DEPS * EMPLOYEE)

Join conditions for materializing the Relationship types of the COMPANY ER schema

ER Relationship	Participating Relations	Join Condition
WORKS_FOR	EMPLOYEE, DEPARTMENT	EMPLOYEE.DNO = DEPARTMENT.DNUMBER
NAMAGES	EMPLOYEE, DEPARTMENT	EMPLOYEE.SSN = DEPARTMENT.MGRSSN
SUPERVISION	EMPLOYEE(E) EMPLOYEE(S)	EMPLOYEE(E).SUPERSSN = EMPLOYEE(S).SSN
WORKS_ON	EMPLOYEE, WORKS_ON, PROJECT	EMPLOYEE.SSN = WORKS_ON.ESSN AND PROJECT.PNUMBER = WORKS_ON.PNO
CONTROLS	DEPARTMENT, PROJECT	DEPARTMENT.DNUMBER = PROJECT.DNUM
DEPENDENTS_OF	EMPLOYEE, DEPENDENT	EMPLOYEE.SSN = DEPENDENT.ESSN

Mapping of ER and Relational Models

ER Model	Relational Model
entity type	"entity" relation
1:1 or 1:N relationship type	foreign key (or "relationship" relation)
M:N relationship type	"relationship relation and two foreign keys
n-ary relationship type	"relationship" relation and n foreign keys
simple attribute	attribute
composite attribute	set of emple component attributes
multivalued attribute	relation and foreign key
value set	domain
key attribute	primary (or secondary) key

Operations of the Relational Algebra

Operation	Purpose	Notation
SELECT	Selects all tuples that satisfy the selection condition from a relation R.	$\sigma_{<selection condition>}(R)$
PROJECT	Produces a new relation with only some of the attributes of R, and removes duplicate tuples.	$\pi_{<attribute list>}(R)$
THETA JOIN	Produces all combinations of tuples from R_1 and R_2 that satisfy the join condition.	$R_1 \bowtie_{<join condition>} R_2$
EQUIJOIN	Produces all the combinations of tuples from R_1 and R_2 that satisfy a join condition with only equality comparisons.	$R_1 \bowtie_{<join condition>} R_2$, or R_1 $_{(<join attributes 1>), (<join attributes 2>)}\bowtie$ 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.	$R_1 *_{<join condition>} R_2$, or $R_1 *_{(<join attributes 1>), (<join attributes 2>)} R_2$ or $R_1 * R_2$

Operations of the Relational Algebra (Continued)

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_1 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 both R_1 and 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 Y	$R_1 \div R_2$