Lecture 11

Relational Algebra (cont'd)

Week 5

Overview

- Join
  - join
  - equijoin and natural join
- Division
- Simplifying relational algebra expressions

Join

$A \bowtie_C B$

Not strictly necessary, but very useful

$$A \bowtie_C B \equiv \sigma_C (A \times B)$$

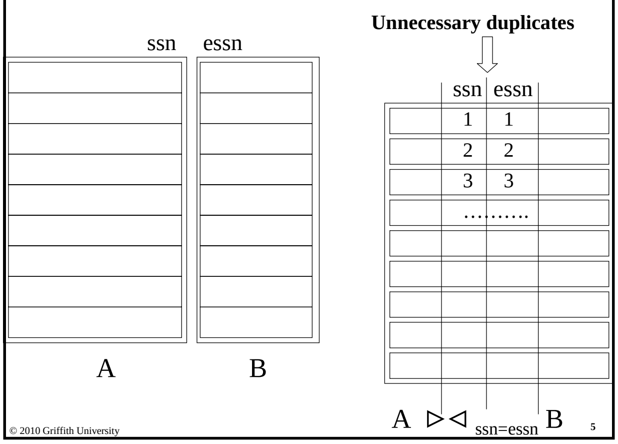
I.e. take the cartesian product (cross product) of A and B and select tuples which satisfy condition C

Equijoin

$$A \bowtie_{\text{equality conditions}} B$$

where the equality conditions prescribe that corresponding attribute values be equal

E.g. Employee $\bowtie_{SSN = ESSN}$ Dependent will join the corresponding tuples of Employee and Dependent



Natural join

- To remove the duplicate columns a variation of equijoin is used

$$A *_{\text{equality conditions}} B$$

Example:

Employee $*_{ssn=essn}$ Dependent

- If no condition is listed, ***all corresponding attributes*** (ones with the same name) are joined through the equality condition
  But, be careful:

  Employee * Dependent

  a) would not work, because there are no attributes with the same name
  b) sometimes attribute names inadvertently join. ***It is best to always list the join condition explicitly!***

Division

A ÷ B

Example:

"List the employees who work on every project"

Take a simplified company schema:

employee(ssn)
project(pno)
works_on(ssn,pno)

- If we knew that every employee works on every project, then the works_on relation would be unnecessary, it could be reconstructed by the cartesian product
  W = employee × project
- if we took away works_on from W:
  W \ works_on
  the result would contain potential, but not actual works_on relationship instances

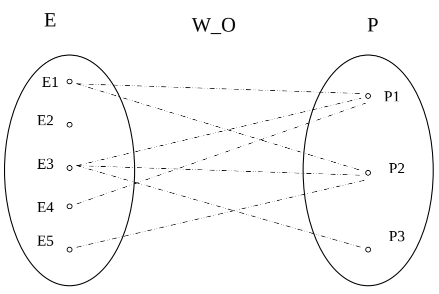
- Therefore

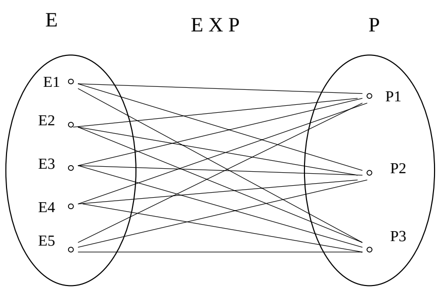
  Π_{ssn} (Employee x Project \ Works_on)

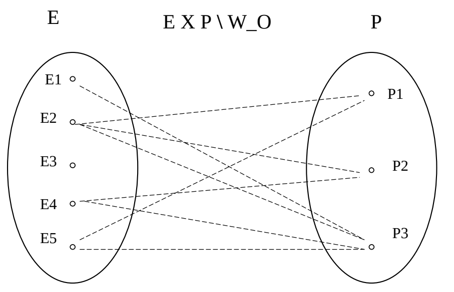
  is the set of emplooyees who do *not* work on every project

- To calculate the set of employees who work on every project we take this away from employee:

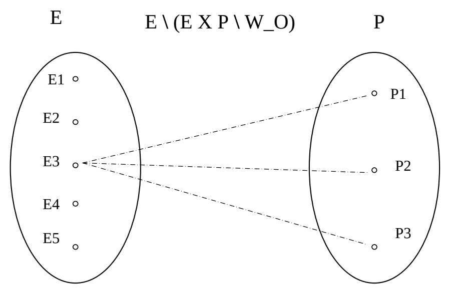
  Π_{ssn} Employee \
  Π_{ssn} (Employee x Project \ Works_on)







Employees who do *not* work on every Project



Employees who work on every Project

Introduce the division operator:

Works_on(ssn,pno) ÷ Project(pno) ≡

Π_{ssn} Employee \

(Π_{ssn} (Employee × Project \ Works_on))

We can do this in general as well:

Definition

A(a,b) ÷ B(b) ≡ the largest set C (a) such that B × C ⊆ A

Simplifying relational algebra expressions

- 10*5 + 10* 7 + 10*8 = 10 * (5+7+8) = 10 * 20 = 200
- In the same way expressions in relational algebra can be simplified based on the discussed properties of the operators
- Query processors evaluate queries using simplification or to the contrary, elaboration so that the execution is cheaper (e.g cutting down on tuples which will later be discarded anyway)

Example

Simpler

$\Pi_{ssn,name}$ (
$\sigma_{name='mary'}$ Employee $*_{dno=dnumber}$
$\sigma_{dname='research'}$ Department) =

$\Pi_{ssn,name}$ (
$\Pi_{ssn,name,dno}$ $\sigma_{name='mary'}$ Employee $*_{dno=dnumber}$
$\Pi_{dnumber}$ $\sigma_{dname='research'}$ Department)

Cheaper to evaluate

Query plan

- Relational algebra operators are implemented as parametric programming language functions, manipulating data structures that implement sets of tuples (relations)
- A query plan is a suitable concatenation (or parallel execution model) of such functions

Query plans can be evaluated ..

- …by the main processor of the computer on which the DBMS runs
- Simple operations, like select or project, can be performed by the disk drive itself - in order to avoid the transfer of massive amounts of data to main memory (later to be discarded anyway)

Conclusion

- Relational algebra has been introduced as an algebra of relations
- Each operator (monadic or binary) works on relations and returns relations
- Additional operations exist to carry out aggregation (this will be discussed only when studying SQL).
- Relational algebra can be used to express queries, as expressions to be evaluated on a database instance
- **Caution:** The result will depend on the actual database instance. The expression should be correct for ***every / any*** database instance.

The end