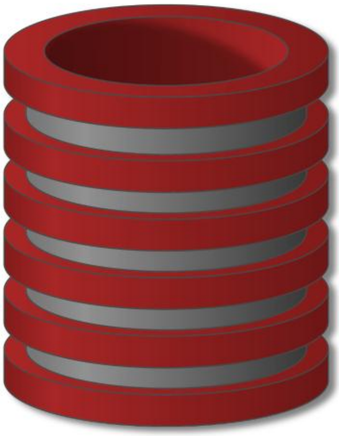


Relational Algebra

Chapter #4
Imran Khan
FCS, IBA

Lecture 4 - Objectives

- Meaning of the term relational completeness.
- How to form queries in relational algebra.
- Categories of relational DML.

Introduction

- Relational algebra and relational calculus are formal languages associated with the relational model.
- Informally, relational algebra is a (high-level) procedural language and relational calculus a non-procedural language.
- However, formally both are equivalent to one another.
- A language that can produce any relation that can be derived using relational calculus is relationally complete.

Relational Algebra

- Relational algebra operations work on one or more relations to define another relation without changing the original relations.

- Both operands and results are relations, so output from one operation can become input to another operation.

- Allows expressions to be nested, just as in arithmetic. This property is called closure.

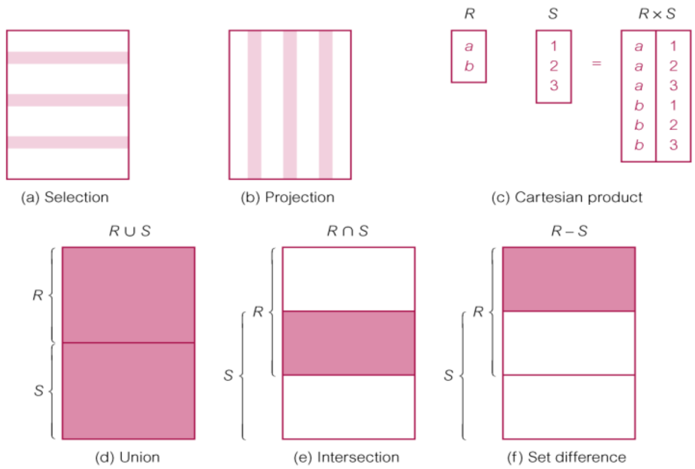
Relational Algebra

- 5 basic operations in relational algebra: Selection, Projection, Cartesian product, Union, and Set Difference.

- These perform most of the data retrieval operations needed.

- Also have Join, Intersection, and Division operations, which can be expressed in terms of 5 basic operations.

Relational Algebra Operations



(a) Selection

(b) Projection

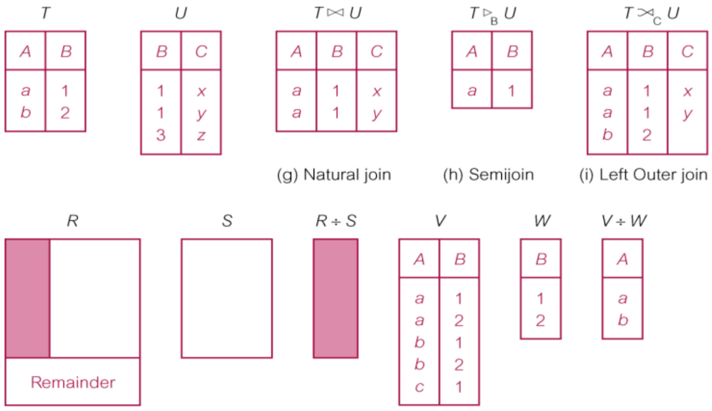
(c) Cartesian product

(d) Union

(e) Intersection

(f) Set difference

Relational Algebra Operations



T

A	B
a	1
b	2

U

B	C
1	x
1	y
3	z

$T \bowtie U$

A	B	C
a	1	x
a	1	y

$T \triangleright_{B} U$

A	B
a	1

$T ⟕_{C} U$

A	B	C
a	1	x
a	1	y
b	2	

(g) Natural join (h) Semijoin (i) Left Outer join

V

A	B
a	1
a	2
b	1
b	2
c	1

W

B
1
2

$V \div W$

A
a
b

(j) Division (shaded area)

Example of division

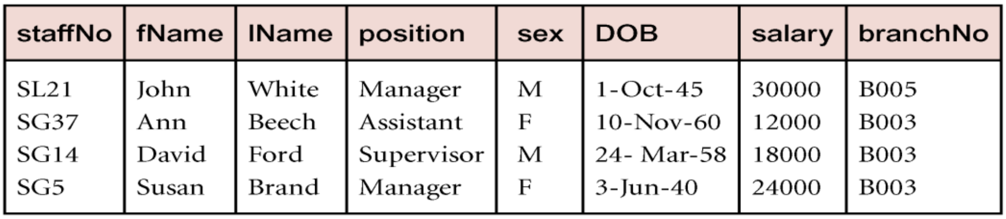
Selection (or Restriction)

- $\sigma_{\text{predicate}}$ (R)
  - Works on a single relation R and defines a relation that contains only those tuples (rows) of R that satisfy the specified condition (predicate).

Example - Selection (or Restriction)

- List all staff with a salary greater than £10,000.

$\sigma_{salary > 10000}$ (Staff)



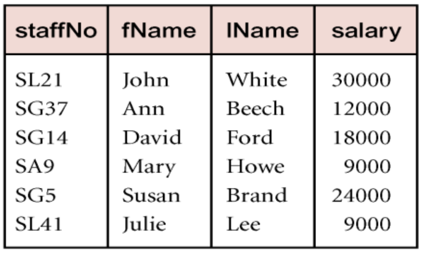
staffNo	fName	lName	position	sex	DOB	salary	branchNo
SL21	John	White	Manager	M	1-Oct-45	30000	B005
SG37	Ann	Beech	Assistant	F	10-Nov-60	12000	B003
SG14	David	Ford	Supervisor	M	24- Mar-58	18000	B003
SG5	Susan	Brand	Manager	F	3-Jun-40	24000	B003

Projection

- $\Pi_{col1, \ldots, coln}$(R)
- Works on a single relation R and defines a relation that contains a vertical subset of R, extracting the values of specified attributes and eliminating duplicates.

Example - Projection

- Produce a list of salaries for all staff, showing only staffNo, fName, lName, and salary details.
- ΠstaffNo, fName, lName, salary(Staff)



staffNo	fName	lName	salary
SL21	John	White	30000
SG37	Ann	Beech	12000
SG14	David	Ford	18000
SA9	Mary	Howe	9000
SG5	Susan	Brand	24000
SL41	Julie	Lee	9000

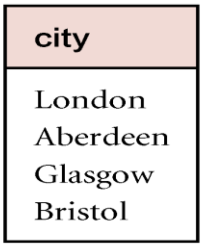
Union

- R ∪ S
  - Union of two relations R and S defines a relation that contains all the tuples of R, or S, or both R and S, duplicate tuples being eliminated.
  - R and S must be union-compatible.
- If R and S have I and J tuples, respectively, union is obtained by concatenating them into one relation with a maximum of (I + J) tuples.

Example - Union

- List all cities where there is either a branch office or a property for rent.

Πcity(Branch) $\cup$ Πcity(PropertyForRent)



city
London
Aberdeen
Glasgow
Bristol

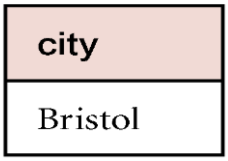
Set Difference

- **R – S**
  - Defines a relation consisting of the tuples that are in relation R, but not in S.
  - R and S must be union-compatible.

Example - Set Difference

– List all cities where there is a branch office but no properties for rent.

– Πcity(Branch) – Πcity(PropertyForRent)



city
Bristol

Intersection

- $R \cap S$
  - Defines a relation consisting of the set of all tuples that are in both R and S.
  - R and S must be union-compatible.

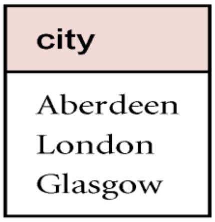
- Expressed using basic operations:

  $R \cap S = R - (R - S)$

Example - Intersection

- List all cities where there is both a branch office and at least one property for rent.

$\Pi\text{city}(\text{Branch}) \cap \Pi\text{city}(\text{PropertyForRent})$



city
Aberdeen
London
Glasgow

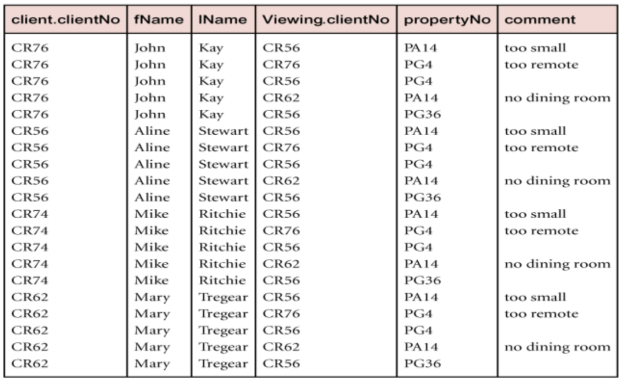
Cartesian product

- R X S
  - – Defines a relation that is the concatenation of every tuple of relation R with every tuple of relation S.

Example - Cartesian Product

- List the names and comments of all clients who have viewed a property for rent.

  (ΠclientNo, fName, lName(Client)) X (ΠclientNo, propertyNo,comment (Viewing))

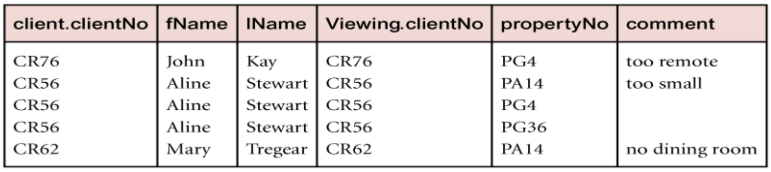


client.clientNo	fName	lName	Viewing.clientNo	propertyNo	comment
CR76	John	Kay	CR56	PA14	too small
CR76	John	Kay	CR76	PG4	too remote
CR76	John	Kay	CR56	PG4	
CR76	John	Kay	CR62	PA14	no dining room
CR76	John	Kay	CR56	PG36	
CR56	Aline	Stewart	CR56	PA14	too small
CR56	Aline	Stewart	CR76	PG4	too remote
CR56	Aline	Stewart	CR56	PG4	
CR56	Aline	Stewart	CR62	PA14	no dining room
CR56	Aline	Stewart	CR56	PG36	
CR74	Mike	Ritchie	CR56	PA14	too small
CR74	Mike	Ritchie	CR76	PG4	too remote
CR74	Mike	Ritchie	CR56	PG4	
CR74	Mike	Ritchie	CR62	PA14	no dining room
CR74	Mike	Ritchie	CR56	PG36	
CR62	Mary	Tregear	CR56	PA14	too small
CR62	Mary	Tregear	CR76	PG4	too remote
CR62	Mary	Tregear	CR56	PG4	
CR62	Mary	Tregear	CR62	PA14	no dining room
CR62	Mary	Tregear	CR56	PG36	

Example - Cartesian Product and Selection

- Use selection operation to extract those tuples where Client.clientNo = Viewing.clientNo.

  sClient.clientNo = viewing.clientNo((ÕclientNo,fName,lName(Client)) X (ÕclientNo,propertyNo,comment(Viewing)))



client.clientNo	fName	lName	Viewing.clientNo	propertyNo	comment
CR76	John	Kay	CR76	PG4	too remote
CR56	Aline	Stewart	CR56	PA14	too small
CR56	Aline	Stewart	CR56	PG4	
CR56	Aline	Stewart	CR56	PG36	
CR62	Mary	Tregear	CR62	PA14	no dining room

◆ **Cartesian product and Selection can be reduced to a single operation called a *Join*.**

Join Operations

- Join is a derivative of Cartesian product.
- Equivalent to performing a Selection, using join predicate as selection formula, over Cartesian product of the two operand relations.
- One of the most difficult operations to implement efficiently in an RDBMS and one reason why RDBMSs have intrinsic performance problems.

Join Operations

- Various forms of join operation
  - Theta join
  - Equijoin (a particular type of Theta join)
  - Natural join
  - Outer join
  - Semijoin

Theta join (θ-join)

- $\mathbf{R} \bowtie_{F} \mathbf{S}$
  - Defines a relation that contains tuples satisfying the predicate F from the Cartesian product of R and S.
  - The predicate F is of the form R.ai θ S.bi where θ may be one of the comparison operators (<, ≤, >, ≥, =, ≠).

Theta join (θ-join)

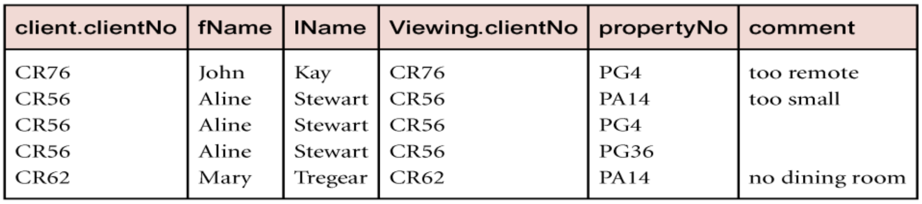
- Can rewrite Theta join using basic Selection and Cartesian product operations.

$$\mathbf{R} \bowtie_{F} \mathbf{S} = \sigma_{F}(\mathbf{R} \times \mathbf{S})$$

- Degree of a Theta join is sum of degrees of the operand relations R and S. If predicate F contains only equality (=), the term Equijoin is used.

Example - Equijoin

- List the names and comments of all clients who have viewed a property for rent.
- (ΠclientNo,fName,lName(Client))$\bowtie$Client.clientNo = Viewing.clientNo (ΠclientNo,propertyNo,comment(Viewing))



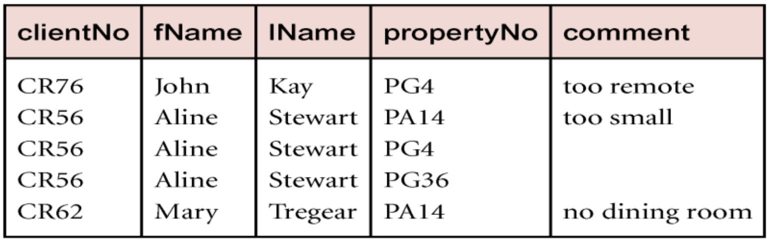
client.clientNo	fName	lName	Viewing.clientNo	propertyNo	comment
CR76	John	Kay	CR76	PG4	too remote
CR56	Aline	Stewart	CR56	PA14	too small
CR56	Aline	Stewart	CR56	PG4	
CR56	Aline	Stewart	CR56	PG36	
CR62	Mary	Tregear	CR62	PA14	no dining room

Natural Join

- R$\bowtie$S
  - An Equijoin of the two relations R and S over all common attributes x. One occurrence of each common attribute is eliminated from the result.

Example - Natural Join

- List the names and comments of all clients who have viewed a property for rent.
- (ΠclientNo,fName,lName(Client)) ⋈ (ΠclientNo,propertyNo,comment(Viewing))



clientNo	fName	lName	propertyNo	comment
CR76	John	Kay	PG4	too remote
CR56	Aline	Stewart	PA14	too small
CR56	Aline	Stewart	PG4	
CR56	Aline	Stewart	PG36	
CR62	Mary	Tregear	PA14	no dining room

Outer join

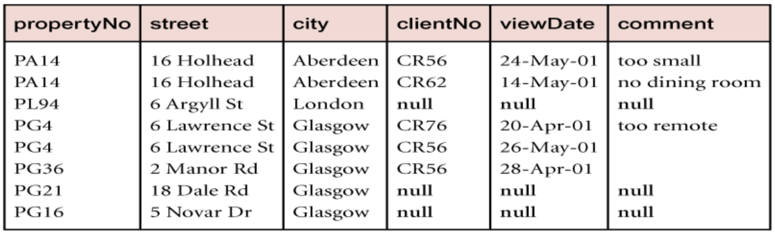
- To display rows in the result that do not have matching values in the join column, use Outer join.

- R ⟕ S
  - (Left) outer join is join in which tuples from R that do not have matching values in common columns of S are also included in result relation.

Example - Left Outer join

- Produce a status report on property viewings.

ΠpropertyNo,street,city(PropertyForRent) ⟕ Viewing



propertyNo	street	city	clientNo	viewDate	comment
PA14	16 Holhead	Aberdeen	CR56	24-May-01	too small
PA14	16 Holhead	Aberdeen	CR62	14-May-01	no dining room
PL94	6 Argyll St	London	null	null	null
PG4	6 Lawrence St	Glasgow	CR76	20-Apr-01	too remote
PG4	6 Lawrence St	Glasgow	CR56	26-May-01	
PG36	2 Manor Rd	Glasgow	CR56	28-Apr-01	
PG21	18 Dale Rd	Glasgow	null	null	null
PG16	5 Novar Dr	Glasgow	null	null	null

Other Languages

- Transform-oriented languages are non-procedural languages that use relations to transform input data into required outputs (e.g. SQL).

- Graphical languages provide user with picture of the structure of the relation. User fills in example of what is wanted and system returns required data in that format (e.g. QBE).

Other Languages

- 4GLs can create complete customized application using limited set of commands in a user-friendly, often menu-driven environment.

- Some systems accept a form of natural language, sometimes called a 5GL, although this development is still a an early stage.