COMP9120

Week 4: Relational Algebra & SQL

Semester 1, 2022

Dr Mohammad Polash
School of Computer Science

THE UNIVERSITY OF SYDNEY

Contents developed by Dr Lijun Chang

Acknowledgement of Country

I would like to acknowledge the Traditional Owners of Australia and recognise their continuing connection to land, water and culture. I am currently on the land of the Gadigal People of the Eora nation and pay my respects to their Elders, past, present and emerging.

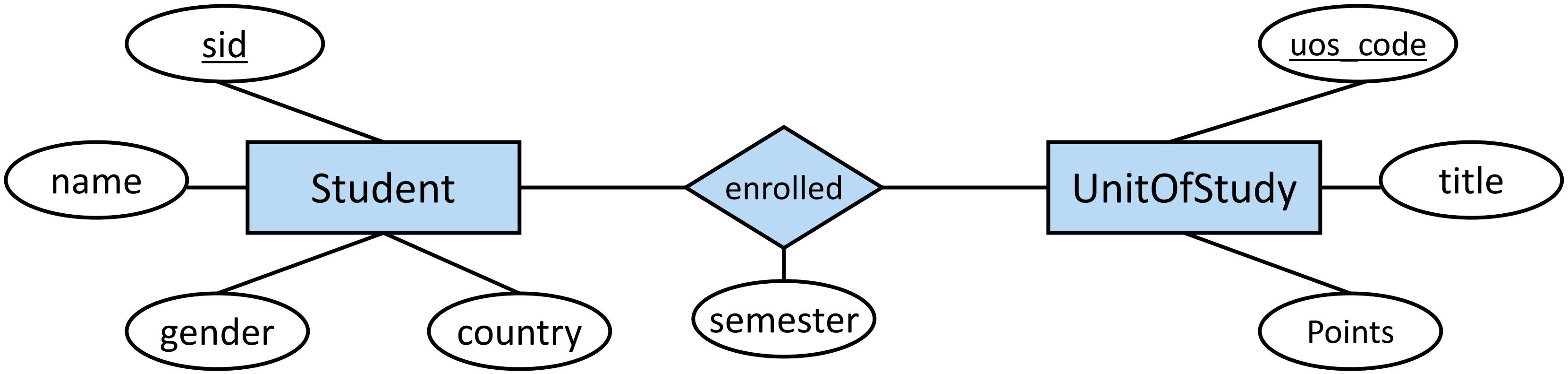
I further acknowledge the Traditional Owners of the country on which you are on and pay respects to their Elders, past, present and future.

Copyright warning

Outline

- **Relational Algebra**: an algebra for relational model
  - Six basic operators
- Introduction to **SQL**
  - Basic SQL queries
  - Join queries
  - Set operations

Running Example



Student			
sid	**name**	**gender**	**country**
1001	Ian	M	AUS
1002	Ha Tschi	F	ROK
1003	Grant	M	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Franzisca	F	GER

Enrolled		
sid	**uos_code**	**semester**
1001	COMP5138	2020-S2
1002	COMP5702	2020-S2
1003	COMP5138	2020-S2
1006	COMP5318	2020-S2
1001	INFO6007	2020-S1
1003	ISYS3207	2020-S2

UnitOfStudy		
uos_code	**title**	**points**
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Management	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
COMP5702	MIT Research Project	18

Relational Algebra

THE UNIVERSITY OF SYDNEY

Exercise: Evaluating a Simple Query

Student			
sid	name	gender	country
1001	Ian	M	AUS
1002	Ha Tschi	F	ROK
1003	Grant	M	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Franzisca	F	GER

Enrolled		
sid	uos_code	semester
1001	COMP5138	2005-S2
1002	COMP5702	2005-S2
1003	COMP5138	2005-S2
1006	COMP5318	2005-S2
1001	INFS6014	2004-S1
1003	ISYS3207	2005-S2

UnitOfStudy		
uos_code	title	points
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Management	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
COMP5702	MIT Research Project	18

Using the above database instance, **find the titles of all units worth 6 credit points**.
Think about the steps we have to take.

title
Relational DBMS
Data Mining
IT Project Management

How does a RDBMS get the answer?

Find the titles of all units worth 6 credit points

Relational Algebra expression:

$\pi_{title}(\sigma_{points=6}(\text{UnitOfStudy}))$

UnitOfStudy

uos_code	title	points
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Management	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
COMP5702	MIT Research Project	18

$\sigma_{points=6}$

uos_code	title	points
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Management	6

π_{title}

title
Relational DBMS
Data Mining
IT Project Management

Example

Student			
sid	name	gender	country
1001	Ian	M	AUS
1002	Ha Tschi	F	ROK
1003	Grant	M	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Franzisca	F	GER

Enrolled		
sid	uos_code	semester
1001	COMP5138	2005-S2
1002	COMP5702	2005-S2
1003	COMP5138	2005-S2
1006	COMP5318	2005-S2
1001	INFS6014	2004-S1
1003	ISYS3207	2005-S2

UnitOfStudy		
uos_code	title	points
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Management	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
COMP5702	MIT Research Project	18

Find the student id of all students who are enrolled in COMP5138.

$\pi_{sid}(\sigma_{uos\_code=\text{'COMP5138'}}(\text{Enrolled}))$

sid
1001
1003

Relational Algebra (RA)

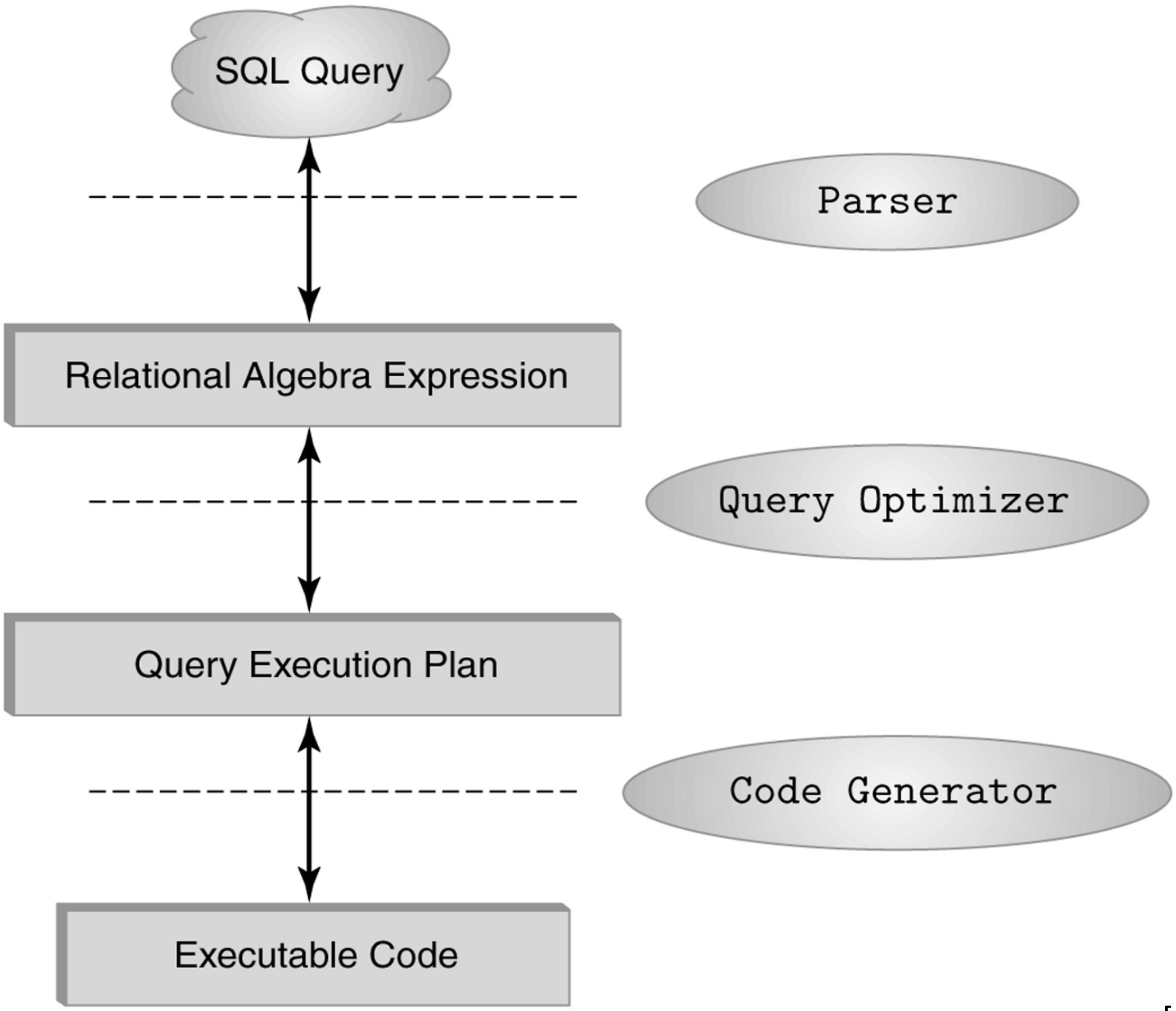
- Relational algebra (RA) is an algebra for ***relational model***
  - Relational algebra operates on **sets**!
  - It is composed using a collection of ***operators*** *(e.g., selection, projection, join)*

    $\pi_{\text{title}}(\sigma_{\text{points=6}}(\text{UnitOfStudy}))$

  - It describes a step-by-step procedure (i.e., describes ***how***) for computing the desired answer

- RA allows us to translate declarative (SQL) queries into **precise** and **optimizable** expressions!

The Role of RA in RDBMS



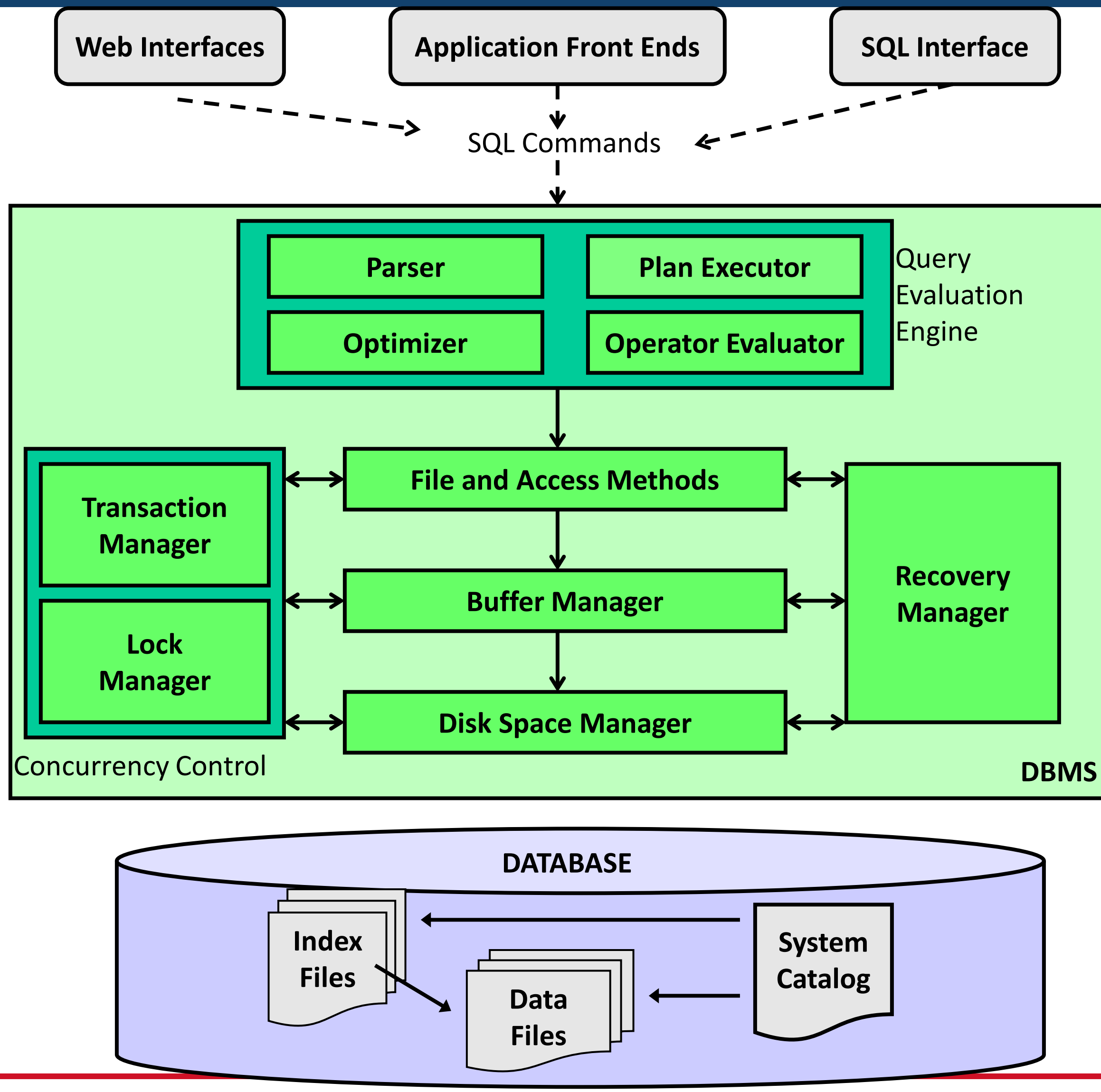
Declarative query (from user)

Translate to relational algebra expression

Find logically equivalent but more efficient relational algebra expression

[cf. Kifer/Bernstein/Lewis, Figure 5.1]

The Role of RA in RDBMS



Basic RA Operators

- Each operator takes one/more relations as inputs and gives a new relation as result
- Operators can be chained together to form expressions (queries)

$$\pi_{title}(\sigma_{points=6}(UnitOfStudy))$$

1. Operators that remove parts of a relation
   - **Selection** (σ) selects a subset of rows from relation.
   - **Projection** (π) deletes unwanted columns from relation.
2. Operators that combine tuples from two relations
   - **Cross-product** ($\times$) combines *every* tuple from two relations.
   - **Join** ($\bowtie$) combines *matching* tuples from two relations.
3. Set Operators
   - **Union** ($\cup$) returns tuples in relation 1 or in relation 2.
   - **Intersection** ($\cap$) returns tuples in relation 1, as well as in relation 2.
   - **Difference** (**-**) returns tuples in relation 1, but not in relation 2.
4. A schema-level ‘rename’ operator
   - **Rename** (ρ) allows us to rename an attribute or a relation.

Projection (π)

- ‘Extracts’ columns for attributes that are in *projection* list.
  - Removes columns that are not in the projection list, then eliminates duplicate rows
  - Schema of the result contains exactly the attributes in the projection list.
- Examples:

$\pi_{name,\ country}\ (Student)$

name	country
Ian	AUS
Ha Tschi	ROK
Grant	AUS
Simon	GBR
Jesse	CHN
Franzisca	GER

$\pi_{country}\ (Student)$

country
AUS
ROK
GBR
CHN
GER

Selection (σ)

- Selects rows that satisfy a ***selection condition***.
  - Schema of the result is the same as the schema of the input relation
  - Example:

$$\sigma_{country='AUS'}(Student)$$

sid	name	gender	country
1001	Ian	M	AUS
1003	Grant	M	AUS

- Result relation can be the input for another relational algebra operation! (***Operator composition***.)
  - Example:

$$\pi_{name}(\sigma_{country='AUS'}(Student))$$

name
Ian
Grant

Exercise

Student			
<u>**sid**</u>	**name**	**gender**	**country**
1001	Ian	M	AUS
1002	Ha Tschi	F	ROK
1003	Grant	M	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Franzisca	F	GER

› Will the following work to "Find the name of the students who live in Australia"?

$$\cancel{\sigma_{country='AUS'}(\pi_{name}(Student))}$$

name
Ian
Ha Tschi
Grant
Simon
Jesse
Franzisca

Selection Condition

- Selection condition is a Boolean combination of terms
  - Each term has the form *attribute* op *constant*, or *attribute1* op *attribute2*
    - op can be <, >, <=, >=, ≠, =
  - Terms are connected by logical connectives:
    - $\wedge$ - means AND
    - $\vee$ - means OR

Student			
sid	**name**	**gender**	**country**
1001	Ian	M	AUS
1002	Ha Tschi	F	ROK
1003	Grant	M	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Franzisca	F	GER

Find out the male Australian students

$$\sigma_{gender='M' \wedge country='AUS'}(Student)$$

THE UNIVERSITY OF SYDNEY

Cross Product (x)

- Defined as: $R \times S = \{t\, s \mid t \in R \wedge s \in S\}$
  - Each tuple of *R* is paired with each tuple of *S*.
  - If R or S is empty, then *R* x *S* is also empty.
  - Resulting schema has one field per field of *R* and *S*, with field names `inherited' if possible.
    - It might end in a conflict with two fields of the same name -> rename needed
- Sometimes also called *Cartesian product*
- Example:

R

A	B
α	1
β	2

x

S

C	D	E
α	10	a
β	10	a
β	20	b
γ	10	b

=

A	B	C	D	E
α	1	α	10	a
α	1	β	10	a
α	1	β	20	b
α	1	γ	10	b
β	2	α	10	a
β	2	β	10	a
β	2	β	20	b
β	2	γ	10	b

Conditional Join ($\bowtie_\Theta$)

- **Conditional Join**: $R \bowtie_\Theta S = \sigma_\Theta (R \times S)$

Example:

$$\text{Student} \bowtie_{\text{Student.f\_name = Lecturer.last\_name} \wedge \text{Student.sid < Lecturer.empid}} \text{Lecturer}$$

sid	given	f_name	gender	country	empid	lecturer_name	last_name	room
1001	Ian	Chung	M	AUS	47112344	Vera	Chung	321
1004	Simon	Poon	M	GBR	12345678	Simon	Poon	431
1004	Simon	Poon	M	GBR	99004400	Josiah	Poon	482
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
…		…	…	…	…		…	…

- Result schema is the same as the cross-product's result schema.
- Sometimes called ***theta-join***.
- ***Equi-Join***: Special case where the condition Θ contains only equalities.

Natural Join (⋈)

› **Natural Join**: R ⋈ S

- Equijoin on all common fields, followed by a projection
  - Result schema is similar to cross-product, but retains only one (specifically, the first) copy of fields for which equality is specified.

Enrolled

sid	uos_code
1001	COMP5138
1002	COMP5702
1003	COMP5138
1006	COMP5318
1001	INFO6007
1003	ISYS3207

⋈

UnitOfStudy

uos_code	title	points
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Mgmt.	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
COMP5702	MIT Research Project	18

=

sid	uos_code	title	points
1001	COMP5138	Relational DBMS	6
1002	COMP5702	MIT Research Project	18
1003	COMP5138	Relational DBMS	6
1006	COMP5318	Data Mining	6
1001	INFO6007	IT Project Mgmt.	6
1003	ISYS3207	IS Project	4

Exercise: Natural Join

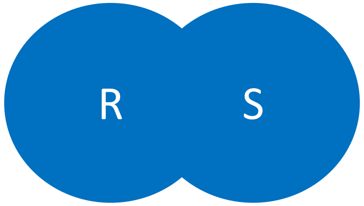
- Given schemas R(A, B, C, D), S(A, C, E), what is the schema of R ⋈ S ?
  - (A, B, C, D, E)

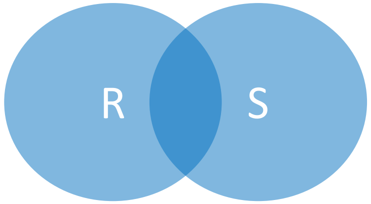
- Given R(A, B, C), S(D, E), what is R ⋈ S ?
  - (A, B, C, D, E)

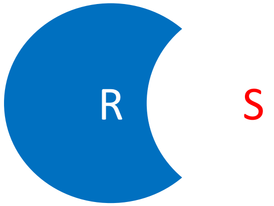
- Given R(A, B), S(A, B), what is R ⋈ S ?
  - (A, B)

Set Operations

- These operations take two input relations *R* and *S*
  - Set Union $R \cup S$
    - Definition: $R \cup S = \{ t \mid t \in R \vee t \in S \}$
  - Set Intersection $R \cap S$
    - Definition: $R \cap S = \{ t \mid t \in R \wedge t \in S \}$
  - Set Difference $R - S$
    - Definition: $R - S = \{ t \mid t \in R \wedge t \notin S \}$







- Important constraint: *R* and *S* have compatible schema
  - *R*, *S* have the *same arity* (same number of fields)
  - `Corresponding' fields must have the same domains

THE UNIVERSITY OF SYDNEY

Exercise: Set Operations

› Suppose you have the following relations. Use a set operation in an RA expression to **return all students who are not postgraduates**.

Student			
sid	name	gender	country
1001	Ian	M	AUS
1002	Ha Tschi	F	ROK
1003	Grant	M	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Franzisca	F	GER

Postgraduate
sid
1003
1004
1005

π_{sid}(Student) - Postgraduate

sid
1001
1002
1006

Rename Operation (ρ)

- Allows us to name, and therefore to refer to, the results of relational-algebra expressions.
- Allows us to refer to a relation by more than one name.
- Notation 1: $\rho_X(E)$
  - returns the expression *E* under the name *X*
- Notation 2: $\rho_{X(A1, A2, \ldots, An)}(E)$
  - (assumes that the relational-algebra expression *E* has arity *n*)
  - returns the result of expression *E* under the name *X*, and with the attributes renamed to *A1, A2, …., An*.
- Note that rename only modifies the schema of a relation!

Example: Rename Operation

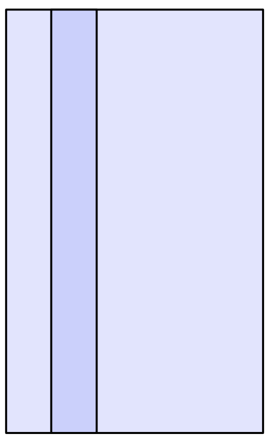
$$\rho_{\text{UOS}(ucode,title,credits)}\,(UnitOfStudy)$$

UnitOfStudy		
uos_code	**title**	**points**
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Management	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
COMP5702	MIT Research Project	18

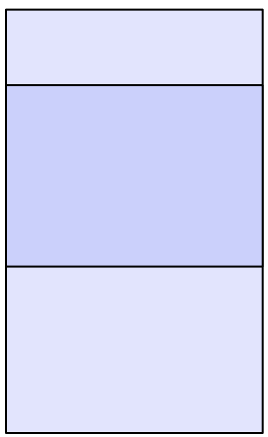
UOS		
ucode	**title**	**credits**
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Management	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
COMP5702	MIT Research Project	18

Visualisation of Relational Algebra Operators

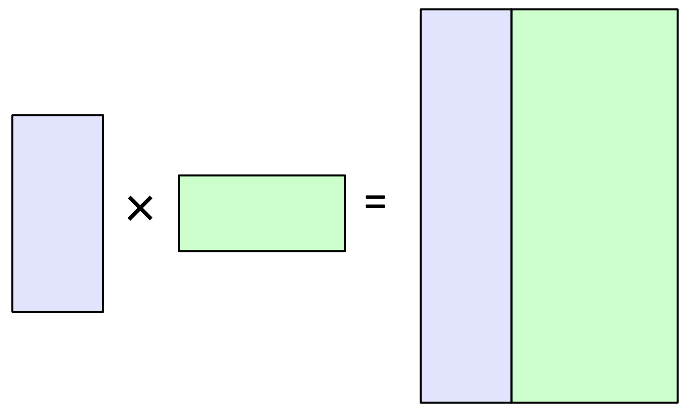
Projection (π)



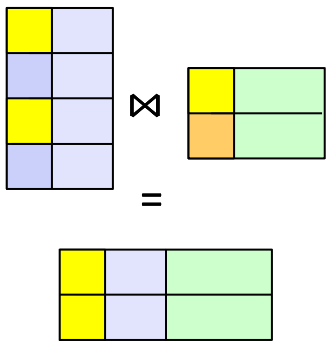
Selection (σ)



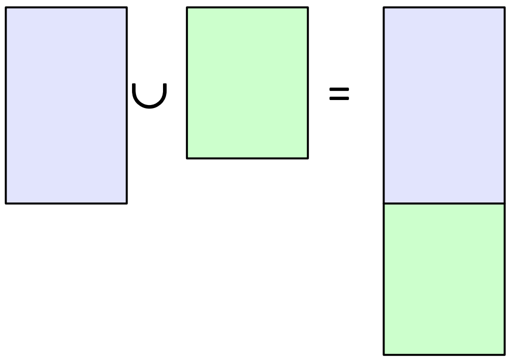
Cross-product ($\times$)



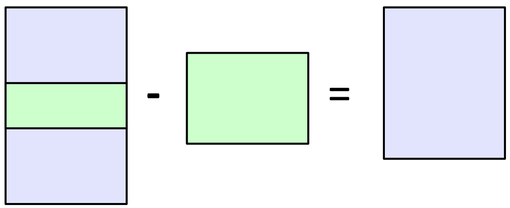
Join ($\bowtie$)



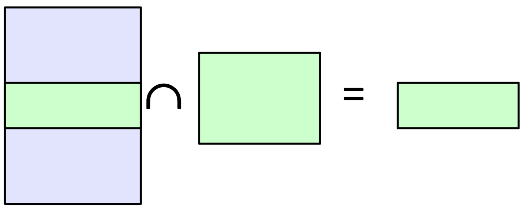
Set Union ($\cup$)



Set Minus (-)



Set Intersection ($\cap$)



Basic Versus Derived Operations

- We can distinguish between basic and derived RA operators
- Only 6 basic operators are required to express everything else:
  - **Selection** (σ) selects a subset of rows from relation.
  - **Projection** (π) deletes unwanted columns from relation.
  - **Cross-product** (**X**) allows us to fully combine two relations.
  - **Union** ($\cup$) returns tuples in relation 1 or in relation 2.
  - **Set Difference** (**-**) returns tuples in relation 1, but not in relation 2.
  - **Rename** (ρ) allows us to rename one field to another name.

- Additional (derived) operations:
  - E.g.: intersection, join. [Not essential, but (very!) useful]
  - E.g., Intersection: $R \cap S = R - (R-S)$

    Join: $R \bowtie_{\theta} S = \sigma_{\theta}(R \times S)$

Remarks

- Different relational algebra expressions can be equivalent but with different execution costs
  - Example: List the names of all students enrolled in 'Relational DBMS'
    - π_{name} ($\sigma_{title=\text{'Relational DBMS'}}$ ((Student $\bowtie$ Enrolled) $\bowtie$ UnitOfStudy))
    - π_{name} (Student $\bowtie$ (Enrolled $\bowtie$ ($\sigma_{title=\text{'Relational DBMS'}}$ (UnitOfStudy))))

Student			
sid	name	gender	country
1001	Ian	M	AUS
1002	Ha Tschi	F	ROK
1003	Grant	M	AUS
1004	Simon	M	GBR
1005	Jesse	F	CHN
1006	Franzisca	F	GER

Enrolled		
sid	uos_code	semester
1001	COMP5138	2020-S2
1002	COMP5702	2020-S2
1003	COMP5138	2020-S2
1006	COMP5318	2020-S2
1001	INFO6007	2020-S1
1003	ISYS3207	2020-S2

UnitOfStudy		
uos_code	title	points
COMP5138	Relational DBMS	6
COMP5318	Data Mining	6
INFO6007	IT Project Management	6
SOFT1002	Algorithms	12
ISYS3207	IS Project	4
COMP5702	MIT Research Project	18

References

- Ramakrishnan/Gehrke (3rd edition - the ‘Cow’ book (2003))
  - **Chapter 4** (you can skip the sections on Relational Calculus)
    one compact section on RA, including a discussion of relational division

- Kifer/Bernstein/Lewis (2nd edition – 2006)
  - Chapter 5.1: *one section on RA that covers everything as discussed here in the lecture*

- Ullman/Widom (3rd edition – 2008)
  - Chapter 2.4
    a nice and gentle introduction to basic RA, leaves out relational division though
  - Chapters 5.1 and 5.2
    goes beyond what we cover here in the lecture by extending RA and also introduces grouping, aggregation and sorting operators

Let’s take a break!

THE UNIVERSITY OF SYDNEY

Introduction to SQL

Outline

- **Basic SQL Queries**
- Join Queries
- Set Operations

SQL: The Structured Query Language

- Relational algebra is a **<u>lower-level</u>** **<u>procedural</u>** query language
  - Hard to understand and write by non-experts
- SQL is the standard **<u>high-level</u>** **<u>declarative</u>** query language for RDBMS
  - Describing *what* data we are interested in, but *not how* to retrieve it.
  - Based on SEQUEL, introduced in the mid-1970's as the query language for IBM's System (<u>S</u>tructured <u>E</u>nglish <u>Que</u>ry <u>L</u>anguage)
- RDBMS internally maps SQL to equivalent relational algebra expressions.

- Many standards out there
  - ANSI SQL, SQL92 (a.k.a. SQL2), SQL99 (a.k.a. SQL3), …
  - RDBMS vendors support various subsets

SQL Overview

- **DDL** (Data Definition Language)
  - Create, drop, or alter the relation schema

- **DML** (Data Manipulation Language)
  - The insertion of new information into the database
  - The deletion of information from the database
  - The modification of information stored in the database
  - The retrieval of information stored in the database
    - A **Query** is a statement requesting the retrieval of information
    - The portion of a DML that involves information retrieval is called a **query language**

- **DCL** (Data Control Language)
  - Commands that control a database, including administering privileges and users

SQL

- Used for queries on single or multiple tables
- keywords:
  - **SELECT** Lists the columns (and expressions) that should be returned from the query
  - **FROM** Indicate the table(s) from which data will be obtained
  - **WHERE** Indicate the conditions to include a tuple in the result
  - **GROUP BY** Indicate the categorization of tuples
  - **HAVING** Indicate the conditions to include a category
  - **ORDER BY** Sorts the result according to specified criteria
- Note: the result of an SQL query is also a table / relation
  - The result table can contain duplicate rows

Select-From-Where (SFW) Queries

› List the names of all students.

```
SELECT  name
  FROM  Student
```

› List the names of all Australian students.

```
SELECT  name
  FROM  Student
 WHERE  country='AUS'
```

$\pi_{name}\,(\,\sigma_{country='AUS'}\,(Student)\,)$

› * in select denotes "all attributes".

```
SELECT *
  FROM Student
```

› General form of SFW query:

```
SELECT  <attributes>
  FROM  <one or more tables>
 WHERE  <conditions>
```

A Select-From-Where query is equivalent to the relational algebra expression:

$$\pi_{A1,\,A2,\,\ldots,\,An}\,(\sigma_{condition}\,(R_1 \times R_2 \times \ldots \times R_m))$$

- **SELECT** corresponds to projection (π) in RA
- **FROM** corresponds to Cartesian product (x) in RA
- **WHERE** corresponds to selection (σ) in RA

A Few Details

- SQL **commands** are <u>not</u> case sensitive:
  - Same: **SELECT**, **Select**, **select**
  - Same: Student, student
- Use single quotes for string constants:
  - ‘aus’ – yes
  - “aus” - no
- String constants are case sensitive:
  - Different: ‘AUS’, ‘aus’, ‘Aus’

Remove Duplicates in Select Clause

- RDBMS allows duplicates in tables as well as in query results.
  - Query result preserves duplicates by default.
  - Example:

SELECT country
FROM Student

country
AUS
ROK
AUS
GBR
CHN
GER

- To eliminate the duplicates, use the keyword **DISTINCT** after **SELECT**.
  - Example: List the distinct countries where students come from.

SELECT DISTINCT country
FROM Student

country
AUS
ROK
GBR
CHN
GER

Arithmetic Expressions in Select Clause

- The **SELECT** clause can contain arithmetic expressions involving the operations +, -, * and /, and operating on constants or attributes of tuples.

- The query:

  SELECT uos_code, title, points*2
    FROM UnitOfStudy

  would return a table which is the same as the UnitofStudy table except that the credit-point-values are doubled.

The Where Clause

- The **WHERE** clause specifies conditions that the result must satisfy
- Comparison operators in SQL: **=** , **>** , **>=** , **<** , **<=** , **<>** (or **!=**)
- Comparison results can be combined using the logical connectives **AND**, **OR**, and **NOT**.
- Comparisons can be applied to results of arithmetic expressions
- Example: Find all UoS codes for units taken by student 1001 in 2021-S2:

```
SELECT uos_code
  FROM Enrolled
 WHERE sid = 1001 AND Semester = '2021-S2'
```

String Operations

- SQL includes a string-matching operator for comparisons on character strings.
  - **LIKE** is used for string matching
  - List the titles of all “COMP” unit of studies.

```
SELECT title
  FROM UnitOfStudy
 WHERE uos_code LIKE ‘COMP%’
```

- Patterns are described using two special characters (“wildcards”):
  - percent (%). The % character matches any substring.
  - underscore (_). The _ character matches any single character.
- SQL supports a variety of string operations such as
  - concatenation (using “||”)
  - converting from upper to lower case (and vice versa)
  - finding string length, extracting substrings, etc.

The Rename Operation

- SQL allows renaming table attributes using the **AS** clause:

  old_name **AS** new_name

- This is very useful to give, e.g., result columns of expressions a meaningful name.
- This can also assign names to tables as shown in example below

- Example:
  - Find the uos_code, credit_points for COMP5318,

    rename the column name uos_code as course_code.

```
SELECT a.uos_code AS course_code, a.credit_points
  FROM unitofstudy a
 WHERE a.uos = 'COMP5318'
```

Order By Clause

- List all students (name) from Australia in alphabetical order.

```
SELECT  name
FROM  Student
WHERE  country='AUS'
ORDER BY  name
```

- Two options (per attribute):
  - **ASC** ascending order (default)
  - **DESC** descending order
- You can order by more than one attribute
  - e.g., **ORDER BY** country **DESC**, name **ASC**

Outline

- Basic SQL Queries
- **Join Queries**
- Set Operations

Join Query

- A join query combines two or more tables into a single table
- The **FROM** clause lists the tables involved in the query
  - corresponds to the Cartesian product of the tables.
  - join-predicates explicitly stated in the **WHERE** clause

- Examples:
  - Find the Cartesian product *Student* x *UnitOfStudy*

```
SELECT *
  FROM Student, UnitofStudy
```

  - Find the student ID, name, and gender of all students enrolled in INFO6007:

```
SELECT sid, name, gender
  FROM Student, Enrolled
 WHERE Student.sid = Enrolled.sid AND
       uos_code = 'INFO6007'
```

Join Example

› Which students did enroll in what semester?

Join involves multiple tables in FROM clause

```
SELECT S.sid, S.name, E.semester
FROM Student S, Enrolled E
WHERE S.sid = E.sid
```

WHERE clause performs the equality check for common columns of the two tables

$$\pi_{S.sid,\ S.name,\ E.semester}\ (\sigma_{S.sid\ =\ E.sid}\ (\rho_S\ (Student) \times \rho_E\ (Enrolled)\ )\ )$$

Aliases

- Some queries need to refer to the same table twice

- In this case, aliases are given to the table name

  - Example: For each academic, retrieve the academic's name, and the name of his or her immediate supervisor.

```
SELECT   L.name, M.name
FROM     Lecturer L, Lecturer M
WHERE    L.manager = M.empid
```

  - We can think of L and M as two different copies of Lecturer;
    L represents lecturers in role of supervisees and M represents lecturers in role of supervisors (managers)

Joins

- **Inner join:** *a join in which rows in the result table must have matching rows in both joining tables. Corresponds to joins in relational algebra*
  - By default, joins in SQL are "**inner joins**". The word "**inner**" can be omitted.
  - **Theta join**: R **JOIN** S **ON** <join condition>
  - **Equi-join:** R **JOIN** S **USING (** <list of attributes> **)**
    - The specified attributes appear only once in the result table
  - **Natural join**: R **NATURAL JOIN** S
- ***Outer join** – a join in which rows that do not have matching values are nonetheless also included (exactly once) in the result relation*
  - ***Left outer join**: includes rows that would be found in an inner join as well as rows from the left table that don't have matches (padded with* NULL *values)*
  - ***Right outer join**: includes rows that would be found in an inner join as well as rows from the right table that don't have matches (padded with* NULL *values)*
  - ***Full outer join**: includes rows that would be found in an inner join as well as rows from the left table and rows from the right table that don't have matches*

SQL Join Operators

- Note that Join operators (a) are specified in the **FROM** clause, and (b) must have both a **join type** and a **join condition**
  - Available join types: **JOIN, LEFT OUTER JOIN, RIGHT OUTER JOIN, FULL OUTER JOIN**
  - Available join conditions: **NATURAL, ON** <join condition>, **USING (** <list of attributes> **)**

e.g: **SELECT** * **FROM** Student **JOIN** Enrolled **USING** (sid)

inner join result

sid	name	birthdate	country	uos_code	semester
112	*'A'*	*01.01.84*	*India*	*SOFT1*	*1*
200	*'B'*	*31.5.79*	*China*	*COMP2*	*2*

e.g: **SELECT** * **FROM** Student **NATURAL LEFT OUTER JOIN** Enrolled

left outer join *result*

sid	name	birthdate	country	uos_code	semester
112	*'A'*	*01.01.84*	*India*	*SOFT1*	*1*
200	*'B'*	*31.5.79*	*China*	*COMP2*	*2*
210	*'C'*	*29.02.82*	*Australia*	*null*	*null*

Outline

- Basic SQL Queries
- Join Queries
- **Set Operations**

Set Operations

- The set operations **UNION**, **INTERSECT**, and **EXCEPT** operate on tables and correspond to the relational algebra operations $\cup$, $\cap$, $-$.
- Each of the above operations automatically eliminates duplicates.
  - First eliminate duplicates from the input tables, and then do the set operation
  - *Suppose a tuple occurs 3 times in R and 1 times in S, then it occurs 0 times in* R **EXCEPT** S
- To retain all duplicates, use the corresponding multiset versions **UNION ALL**, **INTERSECT ALL** and **EXCEPT ALL.**
- Suppose a tuple occurs *m* times in *R* and *n* times in *S,* then it occurs:
  - $m + n$ times in R **UNION ALL** S
  - min(m,n) times in R **INTERSECT ALL** S
  - max(0, $m - n$) times in R **EXCEPT ALL** S

Example: Set Operations

- Find all customer names that have a loan, an account, or both:

```
SELECT customer_name FROM depositor
UNION
SELECT customer_name FROM borrower
```

Depositor(<u>customer_name</u>,account_balance)
Borrower(<u>customer_name</u>, loan_amount)

- Find all customer names that have both a loan and an account

```
SELECT customer_name FROM depositor
INTERSECT
SELECT customer_name FROM borrower
```

- Find all customer names that have an account but no loan

```
SELECT customer_name FROM depositor
EXCEPT
SELECT customer_name FROM borrower
```

Example: Set Operations

- Find students who enrolled in either ‘COMP5138’ or ‘INFO6007’.

```
SELECT sid FROM Enrolled WHERE uos_code='COMP5138'
UNION
SELECT sid FROM Enrolled WHERE uos_code='INFO6007'
```

  - This is equivalent to the following SQL command without set operation

```
SELECT sid
FROM Enrolled
WHERE uos_code='COMP5138' OR uos_code='INFO6007'
```

- Find students who enrolled in both ‘COMP5138’ and ‘INFO6007’.

```
SELECT sid FROM Enrolled WHERE uos_code='COMP5138'
INTERSECT
SELECT sid FROM Enrolled WHERE uos_code='INFO6007'
```

  - This is not equivalent to

```
SELECT sid
FROM Enrolled
WHERE uos_code='COMP5138' AND uos_code='INFO6007'
```

References

- Ramakrishnan/Gehrke (3rd edition - the ‘Cow’ book (2003))
  - **Chapter 5**
    uses the famous ‘Sailor-database’ as examples
- Kifer/Bernstein/Lewis (2nd edition – 2006)
  - Chapter 5
    includes some helpful visualisations on how complex SQL is evaluated
- Ullman/Widom (3rd edition – 2008)
  - Chapter 6
    up-to 6.5 good introduction and overview of all parts of SQL querying
- Silberschatz/Korth/Sudarshan (5th edition - ‘sailing boat’)
  - Sections 3.1-3.6
- Elmasri/Navathe (5th edition)
  - Sections 8.4 and 8.5.1

You should now be able to…

- **…formulate basic SQL Queries**
  - Select-From-Where Query
  - Join queries
  - Set operations
- …know how SQL relates to the relational algebra
  - Write equivalent relational algebra expressions for SQL queries

Next Week

- Advanced SQL
  - Nested Queries
  - Aggregation & Grouping
- NULL Values

- Readings:
  - **Ramakrishnan/Gehrke (Cow book), Chapter 5 & Chapter 4.2.5**
  - Kifer/Bernstein/Lewis book, Chapter 5 & 3.2-3.3
  - Ullman/Widom, Chapter 6

See you next week!

Connect with your group mates!