Introduction to Database Systems: CS312
Advanced queries, joins and aggregates

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Exam 1: Monday 4^{th} April 3:00pm

Study your SLIDES

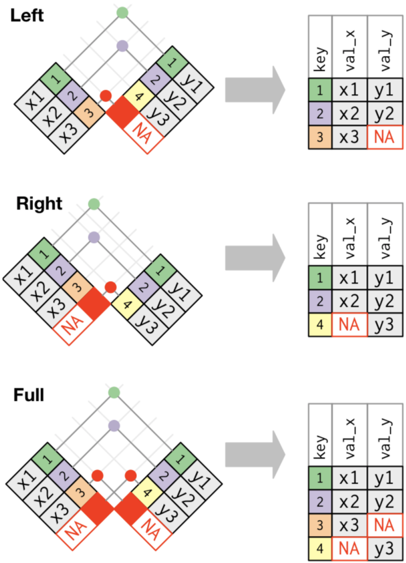
- By Honor code: you cannot talk to your colleagues about exam questions
- Released online: Monday, 4^{th} April by 3:00pm
- You will have 24 hours to take the exam,
- Submit to GitHub by 5^{th} April by 3:00pm
- Builder files to create SQLite3 databases
- Creating a database from a datasets: Adding tables and data
- Writing queries for multiple tables
- Populating, updating tables and data
- Using Primary and foreign keys
- Integrity constraints

Joins: Bringing Data Together

- The SQLite3 `join`-clause is used to combine records from two or more tables in a database.
- A **JOIN** is a means for combining fields from two tables by using values common to each.

Joins: Visual Definitions

Combining Tables



Left

key	val_x	val_y
1	x1	y1
2	x2	y2
3	x3	NA

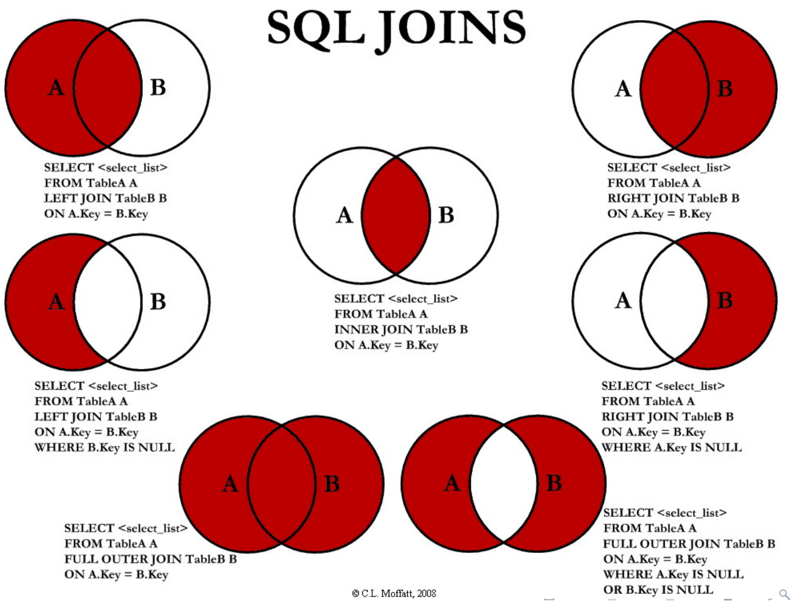
Right

key	val_x	val_y
1	x1	y1
2	x2	y2
4	NA	y3

Full

key	val_x	val_y
1	x1	y1
2	x2	y2
3	x3	NA
4	NA	y3

SQL Code and Venn Diagrams



```
SELECT <select_list>
FROM TableA A
LEFT JOIN TableB B
ON A.Key = B.Key
```

```
SELECT <select_list>
FROM TableA A
INNER JOIN TableB B
ON A.Key = B.Key
```

```
SELECT <select_list>
FROM TableA A
RIGHT JOIN TableB B
ON A.Key = B.Key
```

```
SELECT <select_list>
FROM TableA A
LEFT JOIN TableB B
ON A.Key = B.Key
WHERE B.Key IS NULL
```

```
SELECT <select_list>
FROM TableA A
RIGHT JOIN TableB B
ON A.Key = B.Key
WHERE A.Key IS NULL
```

```
SELECT <select_list>
FROM TableA A
FULL OUTER JOIN TableB B
ON A.Key = B.Key
```

```
SELECT <select_list>
FROM TableA A
FULL OUTER JOIN TableB B
ON A.Key = B.Key
WHERE A.Key IS NULL
OR B.Key IS NULL
```

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An explanation of terms

- SQL joins
  - The **CROSS JOIN**: Matches every row of the first table with every row of the second table. If the input tables have x and y columns, respectively, the resulting table will have $x * y$ columns.
  - The **INNER JOIN**: Creates a new result table by combining column values of two tables (table1 and table2) based upon the join-predicate. The query compares each row of table1 with each row of table2 to find all pairs of rows which satisfy the join-predicate.

Cross joins

Matches every row of the first table with every row of the second table.

- Cross join: *SELECT ... FROM table1 CROSS JOIN table2 ...*
- Automatically testing for equality between the values of every column that exists in both tables

A practical example: Build a matrix of cards

```
 CREATE TABLE ranks (
    rank TEXT NOT NULL
);

CREATE TABLE suits (
    suit TEXT NOT NULL
);

INSERT INTO ranks(rank)
VALUES('2'),('3'),('4'),('5'),('6'),('7'),('8'),('9'),('10'),('J'),('Q'),('K'),('A');

INSERT INTO suits(suit) VALUES('Clubs'),('Diamonds'),('Hearts'),('Spades');

SELECT rank, suit
  FROM ranks
       CROSS JOIN
       suits
ORDER BY suit;
```

Inner joins

Joins two tables where values are equal and disregards the rest.

File: /sandbox/fruitJoin.txt

```
DROP TABLE TableA;
CREATE TABLE TableA (
fruit VARCHAR,
colour VARCHAR);

DROP TABLE TableB;
CREATE TABLE TableB (
fruit VARCHAR,
colour VARCHAR);

INSERT INTO TableA VALUES ("Lemons_A","Yellow");
INSERT INTO TableA VALUES ("Apples_A","Red");
INSERT INTO TableA VALUES ("Grapes_A","Purple");

INSERT INTO TableB VALUES ("Lemons_B","Yellow");
INSERT INTO TableB VALUES ("Apples_B","Red");
INSERT INTO TableB VALUES ("Oranges_B", "Orange");

.tables

SELECT * from TableA;
SELECT* from TableB;

SELECT TableA.fruit, TableA.colour, TableB.colour, TableB.fruit
FROM TableA
INNER JOIN
TableB ON TableB.colour == TableA.colour;
```

Inner joins

Joins two tables where values are equal and disregards the rest.

File: /sandbox/fruitJoin.txt

```
SELECT
  TableA.fruit, TableA.colour,
  TableB.colour, TableB.fruit
FROM
  TableA
INNER JOIN
  TableB ON TableB.colour == TableA.colour;
```

Output

```
Lemons_A|Yellow|Yellow|Lemons_B
Apples_A|Red|Red|Apples_B
```

Cross Join (Cartesian Product Demo)

- Inner join: *SELECT … FROM table1 [INNER] JOIN table2 ON conditional_expression …*
- Combines column values of two tables (table1 and table2) based upon the join-predicate

Create TableA and TableB

```
drop table tableA;
create table tableA (
 num VARCHAR);

drop table tableB;
create table tableB (
 num VARCHAR);
```

Cross Joins (Cartesian Product Demo)

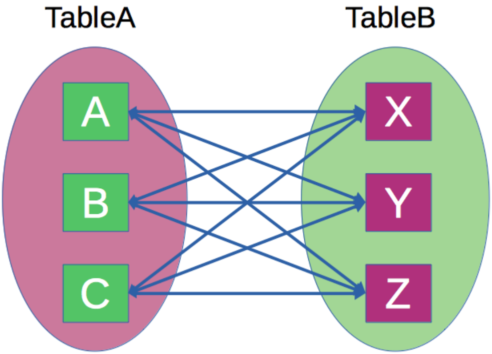
Populate TableA and TableB

```
INSERT INTO tableA VALUES (1);
INSERT INTO tableA VALUES (2);
INSERT INTO tableA VALUES (3);
INSERT INTO tableA VALUES (4);

INSERT INTO tableB VALUES (1);
INSERT INTO tableB VALUES (2);
INSERT INTO tableB VALUES (3);
INSERT INTO tableB VALUES (4);
INSERT INTO tableB VALUES (5);
INSERT INTO tableB VALUES (6);
INSERT INTO tableB VALUES (7);
INSERT INTO tableB VALUES (8);
INSERT INTO tableB VALUES (9);
```

Joins

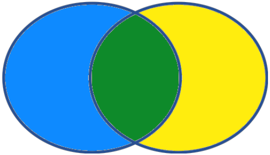
CROSS JOIN: Cartesian Products



SELECT * FROM tableA CROSS JOIN tableB

```
SELECT * from TableA CROSS JOIN TableB;
SELECT * from tableA, TableB;
```

Inner Joins



Left: Blue and Green in Venn Diagram, Above

```
/* inner (left) join */
SELECT TableA.num  FROM TableB  LEFT JOIN TableA  ON TableA.num == TableB.num;
SELECT count(TableA.num)  FROM TableB  LEFT JOIN TableA  ON TableA.num == TableB.num;
```

Right: Yellow and Green in Venn Diagram, Above

```
/* inner (right) join */
 SELECT TableB.num  FROM TableA  LEFT JOIN TableB  ON TableA.num == TableB.num;
 SELECT count(TableB.num)  FROM TableA  LEFT JOIN TableB  ON TableA.num == TableB.num;
```

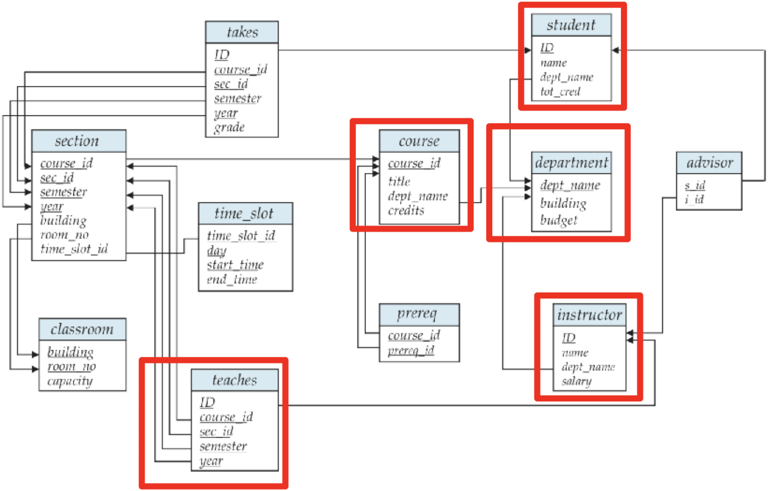
- How many spaces did you count from each query?
- What do the spaces tell you?

New Database

(A New Database!)

New Database

Schema: Red boxes are the tables of today's database study



takes: ID, course_id, sec_id, semester, year, grade

student: ID, name, dept_name, tot_cred

section: course_id, sec_id, semester, year, building, room_no, time_slot_id

course: course_id, title, dept_name, credits

department: dept_name, building, budget

advisor: s_id, i_id

time_slot: time_slot_id, day, start_time, end_time

classroom: building, room_no, capacity

prereq: course_id, prereq_id

instructor: ID, name, dept_name, salary

teaches: ID, course_id, sec_id, semester, year

Figure 2.8 Schema diagram for the university database.

New Database

- Find the database maker file, *campusDB_build.txt*, in your sandbox directory

```
cat campusDB_build.txt | sqlite3 myCampusDB.sqlite3
```

Set Operations

OR & AND

- **OR**: Find all deptNames in the **UNION** of Instructor and Course

    - `select deptName from Instructor UNION select deptName from course;`
    - `select distinct(deptName) from Instructor;`

- **AND**: Find all deptNames in the **INTERSECT** of Instructor and Course

    - `select deptName from Instructor INTERSECT select deptName from Course;`
    - `select distinct(Instructor.deptName) from Instructor, Course where Instructor.deptName == Course.deptName;`

Set Operations

- select distinct(deptName) from Instructor;
- select distinct(deptName) from Course;

- The EXCEPT operator compares the result sets of two queries and returns distinct rows from the left query that are not in the output by the right query.
- Find all deptNames different to both the *Instructor* and *Course*
- Check these two queries below. Why is the output different?

- `select deptName from Instructor EXCEPT select deptName from Course;`
- `select deptName from Course EXCEPT select deptName from Instructor;`

AS clauses

- The **AS** clause is used to rename relations; useful for reducing necessary code in queries
- Ex: *For all instructors in the university who have taught some course, find their names and the course ID of all their taught courses*
  - Select I.name, T.courseID
    FROM `Instructor` AS I , `Teaches` AS T
    WHERE I.ID= T.ID;
- On the second line:
  - the `Instructor` table is renamed to `I`
  - the `Teaches` table is renamed to `T`.

AS clauses

- Another reason to rename a relation is a case where we wish to compare tuples in the same relation.
- We then need to take the Cartesian product of a relation with itself and, without renaming, it becomes impossible to distinguish one tuple from the other.
- Suppose that we want to write the query, *find the names of all instructors whose salary is greater than at least one instructor in the Math department.*
  - SELECT DISTINCT T.name
    FROM Instructor as T ,
    Instructor AS S
    WHERE T.salary> S.salary and S.deptName == "Math"

AS clauses

- Find all names of common teachers in Instructor and Teaches tables

Use AS to implement variables attributes to hold places

-
  ```
  select distinct(Instructor.name) as newName from
  Instructor, teaches where Instructor.ID =
  teaches.ID and newName == "Thompson";
  ```

AS clauses

- Find the names of all Instructors whose salary is greater than at least one Instructor in the Math department.
- select distinct(T.name) from Instructor as T, Instructor as S where T.salary > S.salary and S.deptName == "Math";
- select distinct T.name, T.salary from Instructor as T, Instructor as S where T.salary > S.salary and S.deptName == "Math";
- Reference: select * from Instructor;

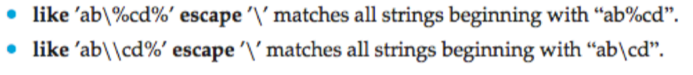
Regular Expression-ish

- Textual *wildcards* to recover information from partial knowledge.
- Finding substrings using the % and _ operators.

- `select name from Instructor where name like "%ille%";`
  - Selects *Miller* from a substring
- `select name from Instructor where name like "%son";`
  - Selects all names followed by "son" substring
- Compare to: *Select * from Instructor;*
- `select name from Instructor where name like "__ll__";`
- `select name from Instructor where name like "__ll___";`
  - Selects "Miller" or "William" from the number of spaces after the "ll";.

Regular Expression-ish

- Find special pattern characters (i.e., ”%” and ”_”) in strings
- SQL even allows the specification of an escape character.



- **like** ’ab\%cd%’ **escape** ’\’ matches all strings beginning with “ab%cd”.
- **like** ’ab\\cd%’ **escape** ’\’ matches all strings beginning with “ab\cd”.

Ordering Results

- SQL allows for sorting the output.
- Output is sorted alphabetically

- `select name from Instructor order by name;`
- `select name,salary from Instructor order by salary;`
  - Provides numerical values in an interval

“Intermediate” Results Using **HAVING**

- The **HAVING** clause enables you to specify conditions that filter which group results appear in the final results.
- The **HAVING** clause must follow the GROUP BY clause in a query and must also precede the ORDER BY clause if used.

Pseudo-code

```
SELECT column1, column2
FROM table1, table2
WHERE [ conditions ]
GROUP BY column1, column2
HAVING [ conditions ]
ORDER BY column1, column2
```

Group By

- Give the number of names, and names of all members of departments who make less than 100000.

```
select count(name), deptName from Instructor GROUP BY
deptName HAVING salary < 100000;
```

- Give the deptNames and the average salaries for departments that begin with the letter ‘C’.

```
select deptName, avg(salary) from Instructor group by
deptName HAVING deptName LIKE "C%";
```

Group By

- Give the department names and salaries from the Instructor group for whose members make between 97K and 100K.

-
  ```
  select deptName, salary from Instructor group by deptName
  HAVING salary < 100000 and salary > 97000;
  ```

- Compare to: Give me deptName and salary information where the salary is between 97K and 100K.

-
  ```
  select deptName, salary from Instructor where salary <
  100000 and salary > 97000 group by deptName;
  ```

Use avg to Query

- `select deptName, avg(salary) from Instructor group by deptName;`
  - Report average salaries for departments
- `select deptName, avgSalary FROM (select deptName, avg(salary) as avgSalary from Instructor group by deptName) where avgSalary > 97000;`
  - Report average salaries larger than $97k. This query is similar to one using the **HAVING** clause. Here we use the **FROM** clause.

Ordering Result Using BETWEEN

- SQL allows for sorting the output by criteria
- Output is sorted for values in an interval

- `select name, salary from Instructor where salary <= 100000 and salary >= 90000;`
- `select name, salary from Instructor where salary between 70000 and 100000;`
  - Query values in their intervals.