Computational Structures in Data Science

SQL

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Announcements

- Extensions:
  - Final Date **all extensions**: End of Dead Week (5/8)
  - Please try not to take that long. ☺
- Ants Due Thursday/Friday!
  - Reminder to sign up for a check off time slot.
  - Go to OH if you'd like to practice!
  - You should have a submission by the time you do your check off.

Review: SQL Basics

- SQL Keywords are case-*insensitive*
  - e.g. `SELECT` and `select` do the same thing
  - I *try* to capitalize them to make it clear what's-what.
- The order of SQL keywords matters
  - e.g. `SELECT ... FROM … WHERE …`
- Every statement ends in a `;`
- Whitespace doesn't matter
  - But indentations and newlines help make queries readable!
- Despite being a standard, differences do exist between databases.

We use `sqlite3`.

A Running example from Data 8

```
# An example of creating a Table from a list of rows.
Table(["Flavor","Color","Price"]).with_rows([
    ('strawberry','pink', 3.55),
    ('chocolate','light brown', 4.75),
    ('chocolate','dark brown', 5.25),
    ('strawberry','pink',5.25),
    ('bubblegum','pink',4.75)])
```

Flavor	Color	Price
strawberry	pink	3.55
chocolate	light brown	4.75
chocolate	dark brown	5.25
strawberry	pink	5.25
bubblegum	pink	4.75


```
culler@CullerMac ~/Classes/CS88-Fa18/ideas/sql> sqlite3 icecream.db
SQLite version 3.13.0 2016-05-18 10:57:30
Enter ".help" for usage hints.
sqlite>
```


Projecting existing tables

- Input table specified by from clause
- Subset of rows selected using a where clause
- Ordering of the selected rows declared using an order by clause

```
select [columns] from [table] where [condition] order by [order] ;
```

```
SELECT * FROM cones ORDER BY Price;
```

ID	Flavor	Color	Price
1	strawberry	pink	3.55
2	chocolate	light brown	4.75
5	bubblegum	pink	4.75
3	chocolate	dark brown	5.25
4	strawberry	pink	5.25
6	chocolate	dark brown	5.25

What's different about this table? IDs!

- *In practice,* every row or *record* in a table should have a **unique unambiguous ID**
- **Why?**
  - How do we know if a record is the same as some other value?
- A properly setup table will handle this for you. ☺
- We'll see it's use in next lecture.

Projection

- A “projection” is a view of a table, it doesn’t alter the state of the table.

```
In [5]: cones.select(['Flavor', 'Price'])
```

Out[5]:

Flavor	Price
strawberry	3.55
chocolate	4.75
chocolate	5.25
strawberry	5.25
bubblegum	4.75
chocolate	5.25

```
sqlite> select Flavor, Price from cones;
Flavor|Price
strawberry|3.55
chocolate|4.75
chocolate|5.25
strawberry|5.25
bubblegum|4.75
chocolate|5.25
```


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Order Of Execution

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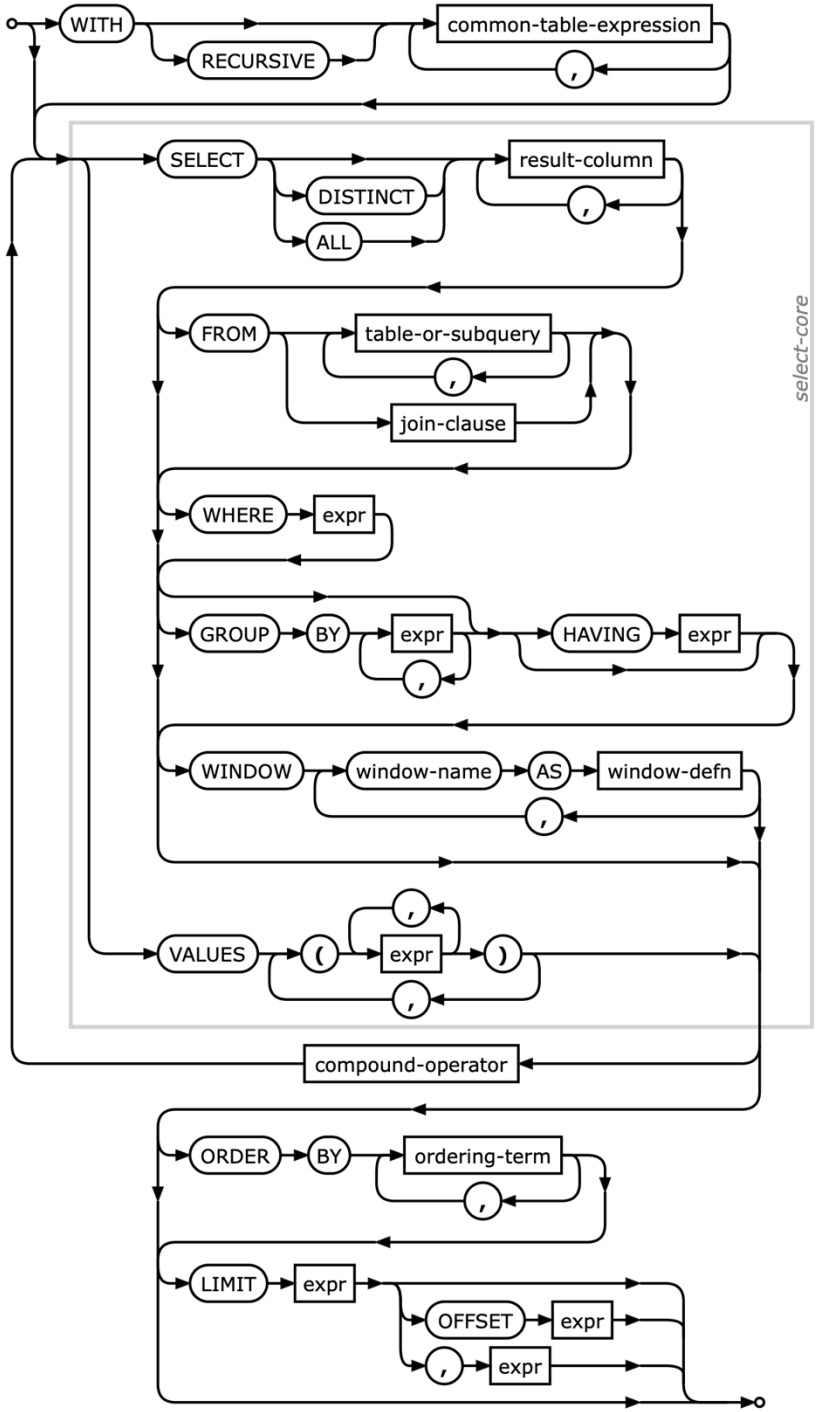
Anatomy of a SQL Statement

From the SQLite Docs

(Don't memorize, but a fairly easy to read reference)



SQL Order Of Execution (for now)

- `SELECT S` 3
- `FROM R1, R2, …` 1
- `WHERE C1` 2

A **SELECT FROM WHERE (SFW)** query is the most standard SQL query structure that extract records from a relation.

Order of execution:

1. **FROM**: Fetch the tables and compute the cross product of R1, R2, …
2. **WHERE**: "Row filter." For each tuple from step 1, keep only those that satisfy condition C1
3. **SELECT**: add to output based on S

SQL Order Of Execution (for now)

- `SELECT S` 3
- `FROM R1, R2, …` 1
- `WHERE C1` 2
- `ORDER BY O1` 4
- `LIMIT X` 5

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Order of execution:

1. **FROM**: Fetch the tables and compute the cross product of R1, R2, …
2. **WHERE**: "Row filter." For each tuple from step 1, keep only those that satisfy condition C1
3. **SELECT**: add to output based on S
4. **ORDER BY**: Sort all the rows according to the conditions O1, etc.
5. **LIMIT**: The final result to the desired number of rows

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Filtering in SQL

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Filtering rows - where

- Set of Table records (rows) that satisfy a condition

```
select [columns] from [table] where [condition] order by [order] ;
```

```
In [5]: cones.select(['Flavor', 'Price'])
```

Out[5]:

Flavor	Price
strawberry	3.55
chocolate	4.75
chocolate	5.25
strawberry	5.25
bubblegum	4.75
chocolate	5.25

```
sqlite> select * from cones where Flavor = "chocolate";
ID|Flavor|Color|Price
2|chocolate|light brown|4.75
3|chocolate|dark brown|5.25
6|chocolate|dark brown|5.25
```

```
cones.where(cones["Price"] > 5)
```

:

ID	Flavor	Color	Price
3	chocolate	dark brown	5.25
4	strawberry	pink	5.25
6	chocolate	dark brown	5.25

SQL:

```
sqlite> select * from cones where Price > 5;
ID|Flavor|Color|Price
3|chocolate|dark brown|5.25
4|strawberry|pink|5.25
6|chocolate|dark brown|5.25
```


SQL Operators for predicate

- use the WHERE clause in the SQL statements such as SELECT, UPDATE and DELETE to filter rows that do not meet a specified condition

SQLite understands the following binary operators, in order from highest to lowest precedence:

```
||
*    /    %
+    -
<<   >>   &    |
<    <=   >    >=
=    ==   !=   <>   IS   IS NOT   IN   LIKE   GLOB   MATCH   REGEXP
AND
OR
```

Supported unary prefix operators are these:

```
-    +    ~    NOT
```

Approximate Matching: LIKE [Docs]

- LIKE compares text to a *pattern*
  - *Case-Insensitive* by default. Means 'a' and 'A' are the same.
- Allows "wildcards" that match any character.
- % means "zero or more" characters at this "spot" in the pattern
- Examples:

```
'abc' LIKE 'abc' → true
'abc' LIKE 'a%' → true
'abc' LIKE '%b%' → true -shortcut for "does abc contain b?"
'b' LIKE '%b%'  → true
'abc' LIKE 'c' → false
```


Summary

- SQL a declarative programming language on relational tables
  - largely familiar to you from data8
  - create, select, where, order, group by, join
- Databases are accessed through Applications
  - e.g., all modern web apps have Database backend
  - Queries are issued through API
    - Be careful about app corrupting the database
- Data analytics tend to draw database into memory and operate on it as a data structure
  - e.g., Tables

Summary – Querying Data

```
SELECT  <col spec>
FROM <table spec>
WHERE <cond spec>
ORDER BY <order spec>
LIMIT <limit spec>;
```


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Subqueries

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Subquery

A **subquery** is a query that appears inside another query statement. Subqueries are also referred to as sub-SELECTs or nested SELECTs.

Three (common) use cases:

1. **Scalar subquery**
2. **EXISTS subquery**
3. `IN`/`ANY`/`ALL` subquery (we'll mostly skip this)

Scalar Subqueries

- If every SELECT statement projects a table, consider this:

```
-- Find the most expensive cone and show its sales
SELECT * FROM sales
WHERE cone_id = (SELECT Id FROM cones ORDER BY
Price DESC LIMIT 1);
```

- Cone_id is a (scalar) single value, but the SELECT statement is a table.
- As long as it is a 1x1 table, sqlite "unpacks" the table.

Exists Subqueries

- EXISTS (and conversely, NOT EXISTS) make it easy to check if some row is in some other table (or set)

```
-- What do we think these two queries do?
SELECT *
FROM cones c
WHERE EXISTS (SELECT 1 FROM sales s WHERE s.cone_id
= c.Id);
SELECT *
FROM cones c
WHERE NOT EXISTS (SELECT 1 FROM sales s WHERE
s.cone_id = c.Id);
```


IN Subqueries

- Similar to EXISTS, but can be more useful for direct comparisons.
- (Optional note: Some people avoid NOT IN because it can lead to confusing comparisons and queries in SQL, especially with missing data.)

-- What do we think these two queries do?

```
SELECT * FROM sales
WHERE cone_id IN (SELECT Id FROM cones WHERE Price
> 3.00);
-- Query 2
SELECT Cashier FROM sales
WHERE cone_id IN (SELECT Id FROM cones WHERE Flavor
= 'Vanilla');
```


EXISTS VS IN

Optional, but compare these two:

```
SELECT * FROM sales s
WHERE EXISTS (
  SELECT 1 FROM cones c
  WHERE c.Id = s.cone_id
  AND c.Price > 3.00
);

SELECT * FROM sales
WHERE cone_id IN (SELECT Id FROM cones WHERE Price >
3.00);
```


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SQL: Joins

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Joining tables

- Two tables are joined by a comma to yield all combinations of a row from each
  - select * from sales, cones;

```
create table sales as
    select "Baskin" as Cashier, 1 as TID union
    select "Baskin", 3 union
    select "Baskin", 4 union
    select "Robin", 2 union
    select "Robin", 5 union
    select "Robin", 6;
```

Cashier	TID
Baskin	1
Robin	2
Baskin	3
Baskin	4
Robin	5
Robin	6

```
sales.join('TID', cones, 'ID')
```

TID	Cashier	Flavor	Color	Price
1	Baskin	strawberry	pink	3.55
2	Robin	chocolate	light brown	4.75
3	Baskin	chocolate	dark brown	5.25
4	Baskin	strawberry	pink	5.25
5	Robin	bubblegum	pink	4.75
6	Robin	chocolate	dark brown	5.25

```
sqlite> select * from sales, cones;
Baskin|1|1|strawberry|pink|3.55
Baskin|1|2|chocolate|light brown|4.75
Baskin|1|3|chocolate|dark brown|5.25
Baskin|1|4|strawberry|pink|5.25
Baskin|1|5|bubblegum|pink|4.75
Baskin|1|6|chocolate|dark brown|5.25
Baskin|3|1|strawberry|pink|3.55
Baskin|3|2|chocolate|light brown|4.75
Baskin|3|3|chocolate|dark brown|5.25
Baskin|3|4|strawberry|pink|5.25
Baskin|3|5|bubblegum|pink|4.75
Baskin|3|6|chocolate|dark brown|5.25
Baskin|4|1|strawberry|pink|3.55
Baskin|4|2|chocolate|light brown|4.75
Baskin|4|3|chocolate|dark brown|5.25
Baskin|4|4|strawberry|pink|5.25
Baskin|4|5|bubblegum|pink|4.75
Baskin|4|6|chocolate|dark brown|5.25
Robin|2|1|strawberry|pink|3.55
Robin|2|2|chocolate|light brown|4.75
Robin|2|3|chocolate|dark brown|5.25
Robin|2|4|strawberry|pink|5.25
Robin|2|5|bubblegum|pink|4.75
Robin|2|6|chocolate|dark brown|5.25
Robin|5|1|strawberry|pink|3.55
Robin|5|2|chocolate|light brown|4.75
Robin|5|3|chocolate|dark brown|5.25
Robin|5|4|strawberry|pink|5.25
Robin|5|5|bubblegum|pink|4.75
Robin|5|6|chocolate|dark brown|5.25
Robin|6|1|strawberry|pink|3.55
Robin|6|2|chocolate|light brown|4.75
Robin|6|3|chocolate|dark brown|5.25
Robin|6|4|strawberry|pink|5.25
Robin|6|5|bubblegum|pink|4.75
Robin|6|6|chocolate|dark brown|5.25
```


Joins

- Joins combine two tables
- A "cross product" or full join gives *all combiniations*
- **This is often not useful!**
- So, we can do an *inner join* where we "combine" rows only on some logical identifier, like an "id"
  - Often this is called a "foreign key" or a reference to an object in another table.

Inner Join

```
SELECT * FROM sales, cones WHERE cone_id =cones.id;
```

When column names conflict we write: `table_name.column_name` in a query.

```
sqlite> SELECT * FROM cones, sales WHERE cone_id=cones.id;
Id|Flavor|Color|Price|Cashier|id|cone_id
1|strawberry|pink|3.55|Baskin|3|1
1|strawberry|pink|3.55|Robin|6|1
2|chocolate|light brown|4.75|Baskin|1|2
2|chocolate|light brown|4.75|Baskin|4|2
2|chocolate|light brown|4.75|Robin|5|2
3|chocolate|dark brown|5.25|Robin|2|3
```


Putting It All Together:

- Which of our cashiers sold the highest value of ice cream?
- First we need to find which cones were sold by whom, then we SUM() the results!

```
sqlite> SELECT Cashier, SUM(Price) as 'Total Sold'
FROM sales, cones WHERE sales.cone_id = cones.id
GROUP BY Cashier;
Cashier|Total Sold
Baskin|13.3
Robin|13.8
```


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SQL: Aggregations

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Unique & DISTINCT values

```
select DISTINCT [columns] from [table] where [condition] order by [order];
```

```
sqlite> select distinct Flavor, Color from cones;
strawberry|pink
chocolate|light brown
chocolate|dark brown
bubblegum|pink
sqlite>
```

```
In [8]: cones.groups(['Flavor', 'Color']).drop('count')
```

Out[8]:

Flavor	Color
bubblegum	pink
chocolate	dark brown
chocolate	light brown
strawberry	pink

```
In [7]: np.unique(cones['Flavor'])
Out[7]: array(['bubblegum', 'chocolate', 'strawberry'], dtype='<U10')
```


Aggregations are Powerful & Common!

```
SELECT date_trunc('day', created) as date, COUNT(*)
FROM users
WHERE created > current_date - interval '1 year'
GROUP BY date;
```

date	count
Apr 17, 2023, 12:00 AM	136
Apr 18, 2023, 12:00 AM	257
Apr 19, 2023, 12:00 AM	326
Apr 20, 2023, 12:00 AM	167
Apr 21, 2023, 12:00 AM	144

Grouping and Aggregations

- The `GROUP BY` clause is used to group rows returned by SELECT statement into a set of summary rows or groups based on values of columns or expressions.
- Apply an aggregate function, such as SUM, AVG, MIN, MAX or COUNT, to each group to output the summary information.

```
cones.group('Flavor')
```

Flavor	count
bubblegum	1
chocolate	3
strawberry	2

```
sqlite> select count(Price), Flavor from cones group by Flavor;
count(Price)|Flavor
1|bubblegum
2|chocolate
2|strawberry
```

```
cones.select(['Flavor', 'Price']).group('Flavor', np.mean)
```

Flavor	Price mean
bubblegum	4.75
chocolate	5.08333
strawberry	4.4

```
sqlite> select avg(Price), Flavor from cones group by Flavor;
avg(Price)|Flavor
4.75|bubblegum
5.0|chocolate
4.4|strawberry
```


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SQL: CREATE and INSERT and UPDATE

(THIS IS NOT TESTED IN 88C!)

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CREATE TABLE

- SQL often used interactively
  - Result of select displayed to the user, but not stored
- Can create a table in many ways
  - Often may just supply a list of columns without data.
- Create table statement gives the result a name
  - Like a variable, but for a permanent object

```
CREATE TABLE [name] AS [select statement];
```


SQL: creating a named table

```
CREATE TABLE cones AS
    select 1 as ID, "strawberry" as Flavor, "pink" as Color,
3.55 as Price union
    select 2, "chocolate", "light brown", 4.75 union
    select 3, "chocolate", "dark brown", 5.25 union
    select 4, "strawberry", "pink",5.25 union
    select 5, "bubblegum", "pink",4.75 union
    select 6, "chocolate", "dark brown", 5.25;
```

Notice how column names are introduced and implicit later on.

Inserting new records (rows)

- A database table is typically a shared, durable repository shared by multiple applications

```
INSERT INTO table(column1, column2,...)
       VALUES (value1, value2,...);
```

```
sqlite> insert into cones(ID, Flavor, Color, Price) values (7, "Vanila", "White", 3.95);
sqlite> select * from cones;
ID|Flavor|Color|Price
1|strawberry|pink|3.55
2|chocolate|light brown|4.75
3|chocolate|dark brown|5.25
4|strawberry|pink|5.25
5|bubblegum|pink|4.75
6|chocolate|dark brown|5.25
7|Vanila|White|3.95
sqlite>
```

```
cones.append((7, "Vanila", "White", 3.95))
cones
```

ID	Flavor	Color	Price
1	strawberry	pink	3.55
2	chocolate	light brown	4.75
3	chocolate	dark brown	5.25
4	strawberry	pink	5.25
5	bubblegum	pink	4.75
6	chocolate	dark brown	5.25
7	Vanila	White	3.95

UPDATING new records (rows)

- If you don’t specify a WHERE, you’ll update all rows!

```
UPDATE table SET column1 = value1, column2 =
value2 [WHERE condition];
```


Summary

```
SELECT  <col spec> FROM <table spec> WHERE <cond spec>
    GROUP BY <group spec> ORDER BY <order spec> ;
```

```
INSERT INTO table(column1, column2,...)
       VALUES (value1, value2,...);
```

```
CREATE TABLE name ( <columns> ) ;
```

```
CREATE TABLE name AS  <select statement> ;
```

