# Computational Structures in Data Science

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# Lecture #23 & 24: Databases & SQL

April 20, 2020

https://cs88.org/

# Updates

- **Nick Weaver will give a guest lecture on Monday. It will be fun!**
- **Final Exam:**
  - **https://piazza.com/class/k5kga9pwx0l754?cid=877**
  - **Please fill out the form linked to pick which time**
  - **You can not take the final if you don't need the points…**
- **Reminder:**
  - **We lowered the grading bins. There's a big gap at both the B- and C- rages to account for P/NP and S/U (grad students). The same grading scheme applies to everyone.**
  - **We are not curving the course, just earn the points you need! But if grades are still really low, we might adjust bins but don't expect to.**
- **Please, please, please fill out course evals!**
  - **https://course-evaluations.berkeley.edu**
  - **The more you tell us, the more you help future students!**

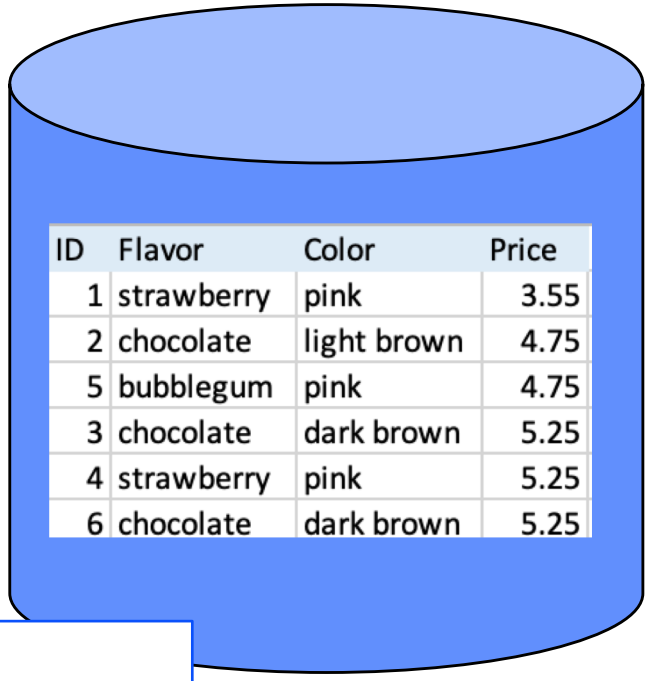
# Why Databases?

- Data lives in files: website access logs, in images, in CSVs and so on…
    - This is an amazing source, but hard to access, aggregate and compute results with.
- Databases provide a mechanism to store vast amounts of data in an *organized* manner.
    - The (often) rely on ”tables” as an abstraction. We
    - There are other kinds of databases, that store “documents” or other forms of data.
- This stuff is the topic of CS186

# Why SQL?

- SQL is a *declarative* programming language for accessing and modifying data in a relational database.
- It is an entirely new way of thinking ("new" in 1970, and new to you now!) that specifies *what* should happen, but not *how* it should happen.
- One of a few major programming paradigms
  - Imperative/Procedural
  - Object Oriented
  - Functional
  - Declarative

# Permanent Data Storage



| 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 |

```
sqlite> .quit
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> .tables
cones
sqlite> select * from cones where Color is "dark brown";
3|chocolate|dark brown|5.25
6|chocolate|dark brown|5.25
sqlite>
```

# 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 …

Regular expression matches are so common that they are built in in SQL.

```
sqlite> select * from cones where Flavor like "%berry%";
Flavor|Color|Price
strawberry|pink|3.55
strawberry|pink|5.25
sqlite>
```

On the other hand, you have the full power of Python to express what you mean.

```
cones.where(cones.apply(lambda x:'berry' in x, 'Flavor'))
```

| ID | Flavor | Color | Price |
|---|---|---|---|
| 1 | strawberry | pink | 3.55 |
| 4 | strawberry | pink | 5.25 |

# Group and Aggregate

- 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
```

# 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')
```

- **Built in to the language or a composable tool?**

# 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
```

# Inner Join

```
select * from sales, cones where TID=ID;
```

```
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 where TID=ID;
Baskin|1|1|strawberry|pink|3.55
Baskin|3|3|chocolate|dark brown|5.25
Baskin|4|4|strawberry|pink|5.25
Robin|2|2|chocolate|light brown|4.75
Robin|5|5|bubblegum|pink|4.75
Robin|6|6|chocolate|dark brown|5.25
sqlite>
```

# SQL: using named tables - `from`

```
select "delicious" as Taste, Flavor, Color from cones
       where Flavor is "chocolate" union
select "other", Flavor, Color from cones
       where Flavor is not "chocolate";
```

```
sqlite> select "delicious" as Taste, Flavor, Color from cones where Flavor is "chocolate" union
   ...> select "other", Flavor, Color from cones where Flavor is not "chocolate";
Taste|Flavor|Color
delicious|chocolate|dark brown
delicious|chocolate|light brown
other|bubblegum|pink
other|strawberry|pink
sqlite>
```

# Queries within queries

- **Any place that a table is named within a select statement, a table could be computed**
  - **As a sub-query**

```
select TID from sales where Cashier is "Baskin";

select * from cones
    where ID in (select TID from sales where Cashier is "Baskin");

sqlite> select * from cones
   ...>     where ID in (select TID from sales where Cashier is "Baskin");
ID|Flavor|Color|Price
1|strawberry|pink|3.55
3|chocolate|dark brown|5.25
4|strawberry|pink|5.25
```

# Inserting new records (rows)

```
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 |

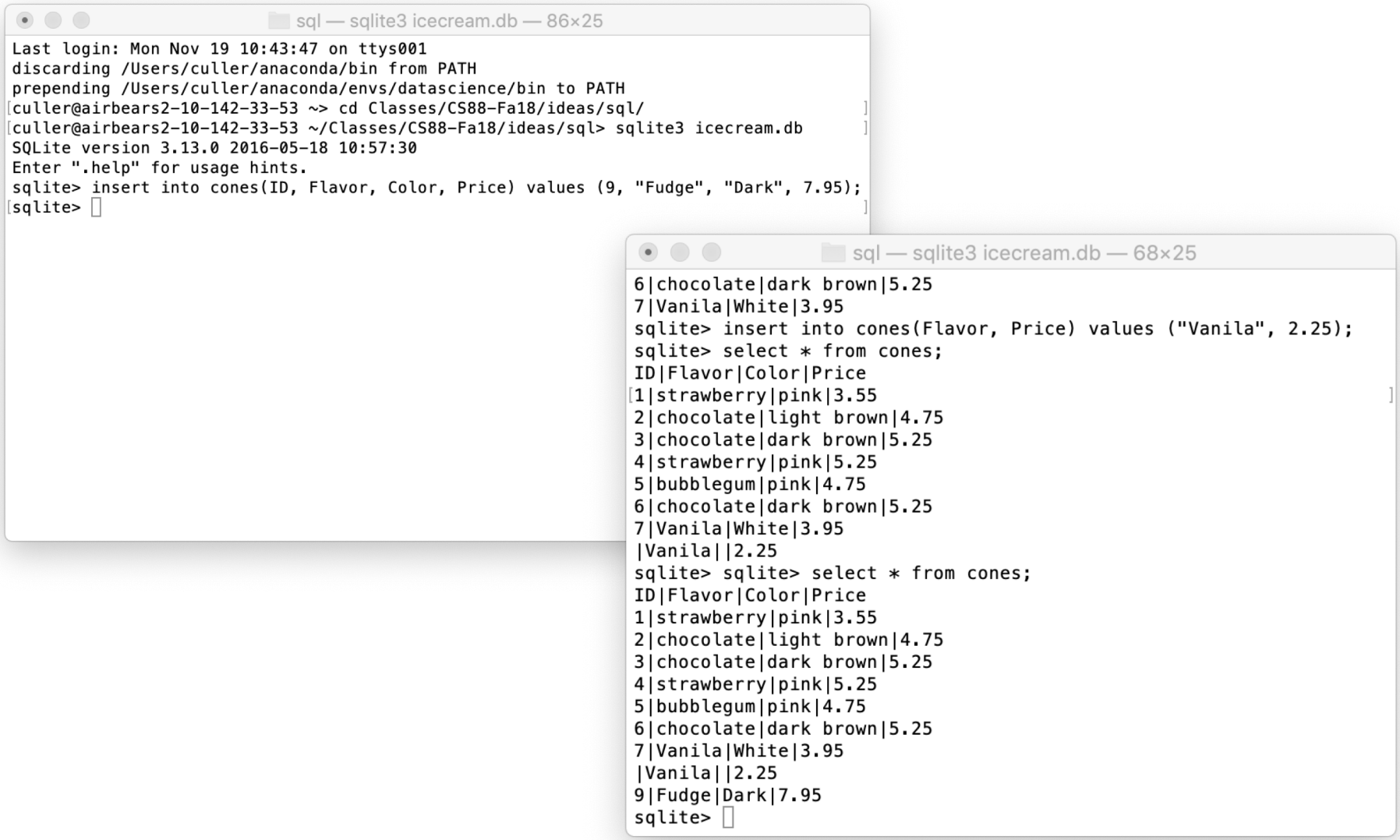
- **A database table is typically a shared, durable repository shared by multiple applications**

# UPDATING new records (rows)

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

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

# Multiple clients of the database




- **All of the inserts update the common repository**

# SQLite python API

```
In [64]: import sqlite3

In [65]: icecream = sqlite3.connect('icecream.db')

In [66]: icecream.execute('SELECT * FROM cones;')
Out[66]: <sqlite3.Cursor at 0x111127960>

In [67]: icecream.execute('SELECT DISTINCT Flavor FROM cones;').fetchall()
Out[67]: [('strawberry',), ('chocolate',), ('bubblegum',)]

In [68]: icecream.execute('SELECT * FROM cones WHERE Flavor is "chocolate";').fetcha
Out[68]: [(2, 'chocolate', 'light brown', 4.75),
          (3, 'chocolate', 'dark brown', 5.25),
          (6, 'chocolate', 'dark brown', 5.25)]
```

# Creating DB Abstractions

```
class SQL_Table(Table):
    """ Extend Table class with methods to read/write a Table
    from/to a table in a SQLite3 database.
    """
    @classmethod
    def read(cls, filepath, table, verbose=False):
        """Create a SQL_Table by reading a table from a SQL database."""

        dbconn = sqlite3.connect(filepath,
                                 detect_types=sqlite3.PARSE_COLNAMES)

        col_names = sqlcol_names(dbconn, table)
        rows = sqlexec(dbconn,'SELECT * from %s;' % table, verbose).fetchal
        dbconn.close()
        return cls(col_names).with_rows(rows)
```

# DB Abstraction (cont)

```
class SQL_Table(Table):
    ...
    def write(self, filepath, table, verbose=False, overwrite=True):
        """Write a Table into a SQL database as a SQL table."""

        dbconn = sqlite3.connect(filepath)
        # Create table and insert each row
        cols = build_list(self.labels)
        sqlexec(dbconn, "CREATE TABLE %s %s;" % (table, cols), verbose)
        for row in self.rows:
            sqlexec(dbconn, 'INSERT INTO %s VALUES %s;' % (table, tuple(row
        dbconn.commit()
        dbconn.close()

    @classmethod
    def cast(cls, table):
        """Return a SQL_Table version of a Table."""
        return cls().with_columns(zip(table.labels, table.columns))
```

# Summary – Part 1

```
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> ;

**DROP TABLE** name ;

# 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
- More in lab