LECTURE 20

# SQL

SQL and Databases: An alternative to Pandas and CSV files.

# Why Databases

- **Why Databases**
- Warmup: SQL Example
- SQL Tables
- Basic SQL Queries
- Basic GROUP BY Operations
- Trickier GROUP BY Operations
- DISTINCT
- SQL and Pandas
- LIKE and CAST
- SQL Joins

# Previously: CSV Files and Pandas

we've usually worked with data stored in CSV files.

`Calls_for_Service.csv` → `pd.read_csv`

| | CASENO | OFFENSE | EVENTDT | EVENTTM | CVLEGEND | CVDOW | InDbDate | Block_Location | BLKADDR | City | State |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 21014296 | THEFT MISD. (UNDER $950) | 04/01/2021 12:00:00 AM | 10:58 | LARCENY | 4 | 06/15/2021 12:00:00 AM | Berkeley, CA\n(37.869058, -122.270455) | NaN | Berkeley | CA |
| 1 | 21014391 | THEFT MISD. (UNDER $950) | 04/01/2021 12:00:00 AM | 10:38 | LARCENY | 4 | 06/15/2021 12:00:00 AM | Berkeley, CA\n(37.869058, -122.270455) | NaN | Berkeley | CA |
| 2 | 21090494 | THEFT MISD. (UNDER $950) | 04/19/2021 12:00:00 AM | 12:15 | LARCENY | 1 | 06/15/2021 12:00:00 AM | 2100 BLOCK HASTE ST\nBerkeley, CA\n(37.864908,... | 2100 BLOCK HASTE ST | Berkeley | CA |
| 3 | 21090204 | THEFT FELONY (OVER $950) | 02/13/2021 12:00:00 AM | 17:00 | LARCENY | 6 | 06/15/2021 12:00:00 AM | 2600 BLOCK WARRING ST\nBerkeley, CA\n(37.86393... | 2600 BLOCK WARRING ST | Berkeley | CA |
| 4 | 21090179 | BURGLARY AUTO | 02/08/2021 12:00:00 AM | 6:20 | BURGLARY - VEHICLE | 1 | 06/15/2021 12:00:00 AM | 2700 BLOCK GARBER ST\nBerkeley, CA\n(37.86066,... | 2700 BLOCK GARBER ST | Berkeley | CA |

Perfectly reasonable workflow for small data that we're not actively sharing with others.

# Brief Databases Overview

A **database** is an organized collection of data.

A **database management system (DBMS)** is a software system that **stores**, **manages**, and **facilitates access** to one or more **databases**.

Why use DBMSes?

- Our data might not be stored in a simple-to-read format such as a CSV (comma-separated values) file.
- Think of a CSV like an Excel sheet.
- Most of the data were given to you in CSV files, but that will not always be the case in the real world.

If our data are stored in a DBMS, we must use languages such as Structured Query Language (SQL) to query for our data.

# Advantages of DBMS over CSV (or similar)

Data Storage:

- **Reliable storage** to survive system crashes and disk failures.
- Optimize to **compute on data that does not fit in memory**.
- Special data structures to **improve performance.**

Data Management:

- Configure how data is **logically organized** and **who has access**.
- Can enforce guarantees on the data (e.g. non-negative bank account balance).
  - Can be used to **prevent data anomalies**.
  - Ensures **safe concurrent operations** on data (multiple users reading and writing simultaneously, e.g. ATM transactions).

# Warmup: SQL Example

- Why Databases
- **Warmup: SQL Example**
- SQL Tables
- Basic SQL Queries
- Basic GROUP BY Operations
- Trickier GROUP BY Operations
- DISTINCT
- SQL and Pandas
- LIKE and CAST
- SQL Joins

# SQL

Today we'll be using a programming language called "Structured Query Language" or SQL.

- SQL is its own programming language, totally distinct from Python.
- SQL is a special purpose programming language used specifically for communicating with databases.
- We will program in SQL using Jupyter notebooks.

Let's see a quick demo of how we can use SQL to connect to a database and view a SQL Table.

# Step 1: Loading the SQL Module

Our first step is to load the SQL module. We do so using the ipython magic command below.

```
%load_ext sql
```

# Step 2: Connecting to a Database

The next step is to connect the database. We use the `%%sql` header to tell Jupyter that this cell represents SQL code rather than Python code.

```
%%sql
sqlite:///data/lec20_basic_examples.db
```

Note that in today's example, our database is stored in a local file. In real world practice, you'd probably connect to a remote server, e.g.

```
%%sql
postgresql://username@mypassw@sjtu.edu.cn/xxx
```

# Example: Showing All Tables in the Database

With the command below, we can enumerate all of the tables in the Database.

```
%%sql
SELECT * FROM sqlite_master WHERE type='table'
```

| type | name | tbl_name | rootpage | sql |
|---|---|---|---|---|
| table | sqlite_sequence | sqlite_sequence | 7 | CREATE TABLE sqlite_sequence(name,seq) |
| table | Dragon | Dragon | 2 | CREATE TABLE Dragon (<br>name TEXT PRIMARY KEY,<br>year INTEGER CHECK (year >= 2000),<br>cute INTEGER<br>) |
| table | Dish | Dish | 4 | CREATE TABLE Dish (<br>name TEXT PRIMARY KEY,<br>type TEXT,<br>cost INTEGER CHECK (cost >= 0)<br>) |
| table | Scene | Scene | 6 | CREATE TABLE Scene (<br>id INTEGER PRIMARY KEY AUTOINCREMENT,<br>biome TEXT NOT NULL,<br>city TEXT NOT NULL,<br>visitors INTEGER CHECK (visitors >= 0),<br>created_at DATETIME DEFAULT (DATETIME('now'))<br>) |

# Example: Showing All Tables in the Database

We see that there are three tables: **Dragon**, **Dish**, and **Scene**.

- The "sql" column gives the command used to create the table.
- Many of the details are beyond the scope of our class. But let's dig into the most important ideas.

| type | name | tbl_name | rootpage | sql |
|---|---|---|---|---|
| table | sqlite_sequence | sqlite_sequence | 7 | CREATE TABLE sqlite_sequence(name,seq) |
| table | Dragon | Dragon | 2 | CREATE TABLE Dragon (<br>name TEXT PRIMARY KEY,<br>year INTEGER CHECK (year >= 2000),<br>cute INTEGER<br>) |
| table | Dish | Dish | 4 | CREATE TABLE Dish (<br>name TEXT PRIMARY KEY,<br>type TEXT,<br>cost INTEGER CHECK (cost >= 0)<br>) |
| table | Scene | Scene | 6 | CREATE TABLE Scene (<br>id INTEGER PRIMARY KEY AUTOINCREMENT,<br>biome TEXT NOT NULL,<br>city TEXT NOT NULL,<br>visitors INTEGER CHECK (visitors >= 0),<br>created_at DATETIME DEFAULT (DATETIME('now'))<br>) |

# Example: Showing the Dragon Table

Now that we're connected, we can start to make queries.

For example, we might show every row in the "Dragon" table.

```
%%sql
SELECT * FROM Dragon;
```

The result is displayed in a format almost identical to our Pandas tables (without an index):

| name | year | cute |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

# SQL Tables

- Why Databases
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- **SQL Tables**
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# SQL Tables

Let's introduce some key SQL Table terminology by looking at the "Dragon" table.

| type | name | tbl_name | rootpage | sql |
|---|---|---|---|---|
| table | sqlite_sequence | sqlite_sequence | 7 | CREATE TABLE sqlite_sequence(name,seq) |
| table | Dragon | Dragon | 2 | CREATE TABLE Dragon (<br>name TEXT PRIMARY KEY,<br>year INTEGER CHECK (year >= 2000),<br>cute INTEGER<br>) |
| table | Dish | Dish | 4 | CREATE TABLE Dish (<br>name TEXT PRIMARY KEY,<br>type TEXT,<br>cost INTEGER CHECK (cost >= 0)<br>) |
| table | Scene | Scene | 6 | CREATE TABLE Scene (<br>id INTEGER PRIMARY KEY AUTOINCREMENT,<br>biome TEXT NOT NULL,<br>city TEXT NOT NULL,<br>visitors INTEGER CHECK (visitors >= 0),<br>created_at DATETIME DEFAULT (DATETIME('now'))<br>) |

# SQL Terminology

**Column** or **Attribute** or **Field**

**Row** or **Record** or **Tuple**

| name<br>TEXT, PK | year<br>INT, >=2000 | cute<br>INT |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

**Dragon**

**Table** or **Relation**

**Column** or **Attribute** or **Field**

**Row** or **Record** or **Tuple**

| name<br>TEXT, PK | year<br>INT, >=2000 | cute<br>INT |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

**Schema:** **ColName**, **Type**, **Constraint**

**Dragon**

**Table** or **Relation**

Every column in a SQL table has three properties: **ColName**, **Type**, and zero or more **Constraints**.

- Pandas series have names and types, but no constraints.

# Example: Showing All Tables in the Database

Every column in a SQL table has three properties: **ColName**, **Type**, and zero or more **Constraints**.

| type | name | tbl_name | rootpage | sql |
|---|---|---|---|---|
| table | sqlite_sequence | sqlite_sequence | 7 | CREATE TABLE sqlite_sequence(name,seq) |
| table | Dragon | Dragon | 2 | CREATE TABLE Dragon (<br>name TEXT PRIMARY KEY,<br>year INTEGER CHECK (year >= 2000),<br>cute INTEGER<br>) |
| table | Dish | Dish | 4 | CREATE TABLE Dish (<br>name TEXT PRIMARY KEY,<br>type TEXT,<br>cost INTEGER CHECK (cost >= 0)<br>) |
| table | Scene | Scene | 6 | CREATE TABLE Scene (<br>id INTEGER PRIMARY KEY AUTOINCREMENT,<br>biome TEXT NOT NULL,<br>city TEXT NOT NULL,<br>visitors INTEGER CHECK (visitors >= 0),<br>created_at DATETIME DEFAULT (DATETIME('now'))<br>) |

2 **constraints**.

# Example Types

Some examples of SQL **types**:

- INT: Integers.
- REAL: Real numbers.
- TEXT: Strings of text.
- BLOB: Arbitrary data, e.g. songs, video files, etc.
- DATETIME: A date and time.

Note: Different implementations of SQL support different types.

- sqllite: https://www.sqlite.org/datatype3.html
- mysql: https://dev.mysql.com/doc/refman/8.0/en/data-types.html

# Example Constraints

Some examples of **constraints**:

- CHECK: Data cannot be inserted which violates the given check constraint.
- PRIMARY KEY: Specifies that this key is used to uniquely identify rows in the table.
- NOT NULL: Null data cannot be inserted for this column.
- DEFAULT: Provides a value to use if user does not specify on insertion.

| type | name | tbl_name | rootpage | sql |
|---|---|---|---|---|
| table | sqlite_sequence | sqlite_sequence | 7 | CREATE TABLE sqlite_sequence(name,seq) |
| table | Dragon | Dragon | 2 | CREATE TABLE Dragon (<br>name TEXT PRIMARY KEY,<br>year INTEGER CHECK (year >= 2000),<br>cute INTEGER<br>) |
| table | Dish | Dish | 4 | CREATE TABLE Dish (<br>name TEXT PRIMARY KEY,<br>type TEXT,<br>cost INTEGER CHECK (cost >= 0)<br>) |
| table | Scene | Scene | 6 | CREATE TABLE Scene (<br>id INTEGER PRIMARY KEY AUTOINCREMENT,<br>biome TEXT NOT NULL,<br>city TEXT NOT NULL,<br>visitors INTEGER CHECK (visitors >= 0),<br>created_at DATETIME DEFAULT (DATETIME('now'))<br>) |

# Primary Keys

For the Dragon table, the “name” of each Dragon is the primary key.

- A primary key is used to uniquely identify each record in the table.
- In other words, no two dragons can have the same name!

Primary key is used under the hood for all sorts of optimizations.

| name<br>TEXT, PK | year<br>INT, >=2000 | cute<br>INT |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

A table can have multiple columns with the PRIMARY KEY **constraints**.

# Basic SQL Queries

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- Trickier GROUP BY Operations
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# The Simplest Query

Recall our simplest query from before:

```
%%sql
SELECT * FROM Dragon;
```

| name | year | cute |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

# Selecting Only Some Columns

We can also SELECT only a subset of the columns:

```
%%sql
SELECT cute, year FROM Dragon;
```

| cute | year |
|---|---|
| 10 | 2010 |
| -100 | 2011 |
| 0 | 2019 |

# The AS Keyword

The AS keyword lets us rename columns during the selection process.

```
%%sql
SELECT cute AS cuteness, year AS birth FROM Dragon;
```

| cuteness | birth |
|---|---|
| 10 | 2010 |
| -100 | 2011 |
| 0 | 2019 |

# Newline Separators

It is common to use a new line to make SQL code more readable. Compare:

```
%%sql
SELECT cute AS cuteness, year AS birth FROM Dragon;
```

```
%%sql
SELECT cute AS cuteness,
       year AS birth
FROM Dragon;
```

| cuteness | birth |
|---|---|
| 10 | 2010 |
| -100 | 2011 |
| 0 | 2019 |

# The WHERE Keyword

To select only some rows of a table, we can use the WHERE keyword.

columns

```
SELECT name, year
FROM Dragon
WHERE cute > 0;
```

table

condition

The Row Where Dragon

| name | year | cute |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

**Dragon**

| name | year |
|---|---|
| hiccup | 2010 |

**Result**

# The OR Keyword

The OR keyword lets us form a disjunctive condition.

- The AND and NOT keywords also exist.

columns

| name | year | cute |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

**Dragon**

```
SELECT name, cute, year
FROM Dragon
WHERE cute > 0 OR year > 2013;
```

table

condition

| name | cute | year |
|---|---|---|
| hiccup | 10 | 2010 |
| dragon 2 | 0 | 2019 |

**Result**

# ORDER BY

The ORDER BY keyword lets you sort a Table.

all columns

```
SELECT *
FROM Dragon
ORDER BY cute DESC;
```

table

column or ASC

| name | year | cute |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

**Dragon**

| name | year | cute |
|---|---|---|
| hiccup | 2010 | 10 |
| dragon 2 | 2019 | 0 |
| drogon | 2011 | -100 |

**Result**

# LIMIT

The LIMIT keyword lets you retrieve N rows.

- Example below is similar to `.head(2)` in pandas.
- Unless you use ORDER BY, there is no guaranteed order!

all columns

```
SELECT *
FROM Dragon
LIMIT 2;
```

table

number of result rows

| name | year | cute |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

**Dragon**

| name | year | cute |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |

**Result**

# OFFSET

The OFFSET keyword lets you tell SQL to see later rows when limiting.

- Unless you use ORDER BY, there is no guaranteed order!

all columns

```
SELECT *
FROM Dragon
LIMIT 2
OFFSET 1;
```

table

where to start

| name | year | cute |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

**Dragon**

| name | year | cute |
|---|---|---|
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

**Result**

# Summary So Far

```
SELECT <column list>
FROM <table>
[WHERE <predicate>]
[ORDER BY <column list>]
[LIMIT <number of rows>]
[OFFSET <number of rows>];
```

# Basic GROUP BY Operations

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# The Dish Table

## Dish

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# The Dish Table

```
SELECT type
FROM Dish;
```

| type |
|---|
| entree |
| entree |
| entree |
| appetizer |
| appetizer |
| appetizer |
| dessert |

## Dish

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# GROUP BY (similar to groupby in Pandas)

```
SELECT type
FROM Dish
GROUP BY type;
```

| type |
| --- |
| appetizer |
| dessert |
| entree |

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
| --- | --- | --- |
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Using GROUP BY and MAX (similar to groupby().max() in pandas)

```
SELECT type, MAX(cost)
FROM Dish
GROUP BY type;
```

| type | MAX(cost) |
|---|---|
| appetizer | 4 |
| dessert | 5 |
| entree | 10 |

Note that "`type, MAX(cost)`" is called a "column expression list".

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Using GROUP BY and SUM (similar to groupby().sum() in pandas)

```
SELECT type, SUM(cost)
FROM Dish
GROUP BY type;
```

| type | SUM(cost) |
|---|---|
| appetizer | 12 |
| dessert | 5 |
| entree | 24 |

For more aggregation functions see
https://www.sqlite.org/lang_aggfunc.html

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| ~~pork~~ bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Using Multiple Aggregation Functions

```
SELECT type,
       SUM(cost),
       MIN(cost),
       MAX(name)
FROM Dish
GROUP BY type;
```

What do you think will happen?

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Using Multiple Aggregation Functions

```
SELECT type,
       SUM(cost),
       MIN(cost),
       MAX(name)
FROM Dish
GROUP BY type;
```

| type | SUM(cost) | MIN(cost) | MAX(name) |
|---|---|---|---|
| appetizer | 12 | 4 | potsticker |
| dessert | 5 | 5 | ice cream |
| entree | 24 | 7 | taco |

## Dish

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Summary

```
SELECT <column expression list>
FROM <table>
[WHERE <predicate>]
[GROUP BY <column>]
[ORDER BY <column list>]
[LIMIT <number of rows>]
[OFFSET <number of rows>];
```

# Trickier GROUP BY Operations

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# Using GROUP BY and COUNT (similar to groupby().count() in pandas)

```
SELECT type, COUNT(cost)
FROM Dish
GROUP BY type;
```

| type | COUNT(cost) |
|---|---|
| appetizer | 3 |
| dessert | 1 |
| entree | 3 |

`COUNT(c)` returns the number of non-null entries in a column c.

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Using GROUP BY and COUNT(*) (similar to groupby().size() in pandas)

```
SELECT type, COUNT(*)
FROM Dish
GROUP BY type;
```

| type | COUNT(*) |
|---|---|
| appetizer | 3 |
| dessert | 1 |
| entree | 3 |

`COUNT(*)` returns the number of rows in each group, including rows with nulls.

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Using GROUP BY and nothing [equivalent to groupby().agg(None) in pandas)

```
SELECT type, cost
FROM Dish
GROUP BY type;
```

Implementation dependent:

- In some variants of SQL, this is allowed.
- In some variants, it is a syntax error.

This is considered bad practice.

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |

MS SQL:

> Column Dish.cost' is invalid in the select list because it is not contained in either an aggregate function or the GROUP BY clause.

# GROUP BY Multiple Columns

```
SELECT type, cost
FROM Dish
GROUP BY type, cost;
```

| type | cost |
|---|---|
| appetizer | 4 |
| dessert | 5 |
| entree | 7 |
| entree | 10 |

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# GROUP BY Multiple Columns

```
SELECT type, cost
FROM Dish
GROUP BY type, cost;
```

| type | cost |
|---|---|
| appetizer | 4 |
| dessert | 5 |
| entree | 10 |

How would we add a third column giving us the number of rows that match each type/cost tuple?

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| [illegible]s | appetizer | 4 |
| [illegible]sticker | appetizer | 4 |
| ice cream | dessert | 5 |

# GROUP BY Multiple Columns

```
SELECT type, cost, COUNT(*)
FROM Dish
GROUP BY type, cost;
```

| type | cost | COUNT(*) |
|---|---|---|
| appetizer | 4 | 3 |
| dessert | 5 | 1 |
| entree | 7 | 2 |
| entree | 10 | 1 |

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| ~~pork~~ bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Prelude to Filtering Groups: Counting the Size of Each type Group

```
SELECT type, COUNT(*)
FROM Dish
GROUP BY type;
```

| type | COUNT(*) |
|---|---|
| appetizer | 3 |
| dessert | 1 |
| entree | 3 |

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| ~~pork~~ bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Filtering Groups with HAVING (similar to groupby("type").filter(lambda f: max(f["cost"]) < 8))

```
SELECT type, COUNT(*)
FROM Dish
GROUP BY type
HAVING MAX(cost) < 8;
```

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Filtering Groups with HAVING (similar to groupby("type").filter(lambda f: max(f["cost"]) < 8))

```
SELECT type, COUNT(*)
FROM Dish
GROUP BY type
HAVING MAX(cost) < 8;
```

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Filtering Groups with HAVING (similar to groupby("type").filter(lambda f: max(f["cost"]) < 8))

```
SELECT type, COUNT(*)
FROM Dish
GROUP BY type
HAVING MAX(cost) < 8;
```

| type | COUNT(*) |
|---|---|
| appetizer | 3 |
| dessert | 1 |

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Exercise: Difference Between HAVING and WHERE

```
SELECT type, COUNT(*)
FROM Dish
WHERE cost < 8
GROUP BY type;
```

Try to predict what happens!

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Exercise: Difference Between HAVING and WHERE

```
SELECT type, COUNT(*)
FROM Dish
WHERE cost < 8
GROUP BY type;
```

| type | COUNT(*) |
|---|---|
| appetizer | 3 |
| dessert | 1 |
| entree | 2 |

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

## Summary

```
SELECT <column expression list>
FROM <table>
[WHERE <predicate>]
[GROUP BY <column list>]
[HAVING <predicate>]
[ORDER BY <column list>]
[LIMIT <number of rows>]
[OFFSET <number of rows>];
```

# Distinct

- Why Databases
- Warmup: SQL Example
- SQL Tables
- Basic SQL Queries
- Basic GROUP BY Operations
- Trickier GROUP BY Operations
- **DISTINCT**
- SQL and Pandas
- LIKE and CAST
- SQL Joins

```
SELECT DISTINCT type
FROM Dish
WHERE cost < 9;
```

| type |
| --- |
| entree |
| appetizer |
| dessert |

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
| --- | --- | --- |
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

```
SELECT DISTINCT type, cost
FROM Dish
WHERE cost < 9;
```

| type | cost |
|---|---|
| entree | 7 |
| appetizer | 4 |
| dessert | 5 |

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

```
SELECT DISTINCT type, cost
FROM Dish;
```

| type | cost |
|---|---|
| entree | 10 |
| entree | 7 |
| appetizer | 4 |
| dessert | 5 |

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# DISTINCT vs. GROUP BY

```
SELECT DISTINCT type, cost
FROM Dish;
```

| type | cost |
|---|---|
| entree | 10 |
| entree | 7 |
| appetizer | 4 |
| dessert | 5 |

**Dish**

| name TEXT, PK | type TEXT | cost INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

```
SELECT type, cost
FROM Dish
GROUP BY type, cost;
```

| type | cost |
|---|---|
| appetizer | 4 |
| dessert | 5 |
| entree | 7 |
| entree | 10 |

**Dish**

| name TEXT, PK | type TEXT | cost INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

To get a tables of unique tuples, we saw we could use SELECT DISTINCT or GROUP BY.

- Better style to use SELECT DISTINCT for unique values (or tuples).
- GROUP BY is primarily intended for use with aggregation operations.
  - I think of the example above as a degenerate use of GROUP BY.

# DISTINCT in Column Expressions

```
SELECT type, AVG(DISTINCT cost)
FROM Dish
GROUP BY type;
```

| type | AVG(DISTINCT cost) |
|---|---|
| appetizer | 4.0 |
| dessert | 5.0 |
| entree | 8.5 |

Since 10 and 7 are the only two unique cost values, the average of these two is 8.5.

**Dish**

| name<br>TEXT, PK | type<br>TEXT | cost<br>INTEGER, >=0 |
|---|---|---|
| ravioli | entree | 10 |
| pork bun | entree | 7 |
| taco | entree | 7 |
| edamame | appetizer | 4 |
| fries | appetizer | 4 |
| potsticker | appetizer | 4 |
| ice cream | dessert | 5 |

# Summary of SQL Syntax So Far

```
SELECT [DISTINCT] <column expression list>
FROM <table>
[WHERE <predicate>]
[GROUP BY <column list>]
[HAVING <predicate>]
[ORDER BY <column list>]
[LIMIT <number of rows>]
[OFFSET <number of rows>];
```

Note: Column Expressions may include aggregation functions (**MAX**, **MIN**, etc) and **DISTINCT**.

Next lecture: `FROM <list of tables>`

# SQL and Pandas

- Why Databases
- Warmup: SQL Example
- SQL Tables
- Basic SQL Queries
- Basic GROUP BY Operations
- Trickier GROUP BY Operations
- DISTINCT
- **SQL and Pandas**
- LIKE and CAST
- SQL Joins

# %%sql

We just saw how we could use the %%sql magic command to run SQL queries in a Jupyter notebook.

```
%%sql
SELECT * FROM Dragon;
```

| name | year | cute |
|---|---|---|
| hiccup | 2010 | 10 |
| drogon | 2011 | -100 |
| dragon 2 | 2019 | 0 |

In this section of lecture, we'll see how to use the sqlalchemy Python library to allow communication between pandas and SQL databases.

# Example

```
import sqlalchemy
# create a SQL Alchemy connection to the database
engine = sqlalchemy.create_engine("sqlite:///data/lec20_basic_examples.db")
connection = engine.connect()

pd.read_sql("""
SELECT type, MAX(cost)
FROM Dish
GROUP BY type;""", connection)
```

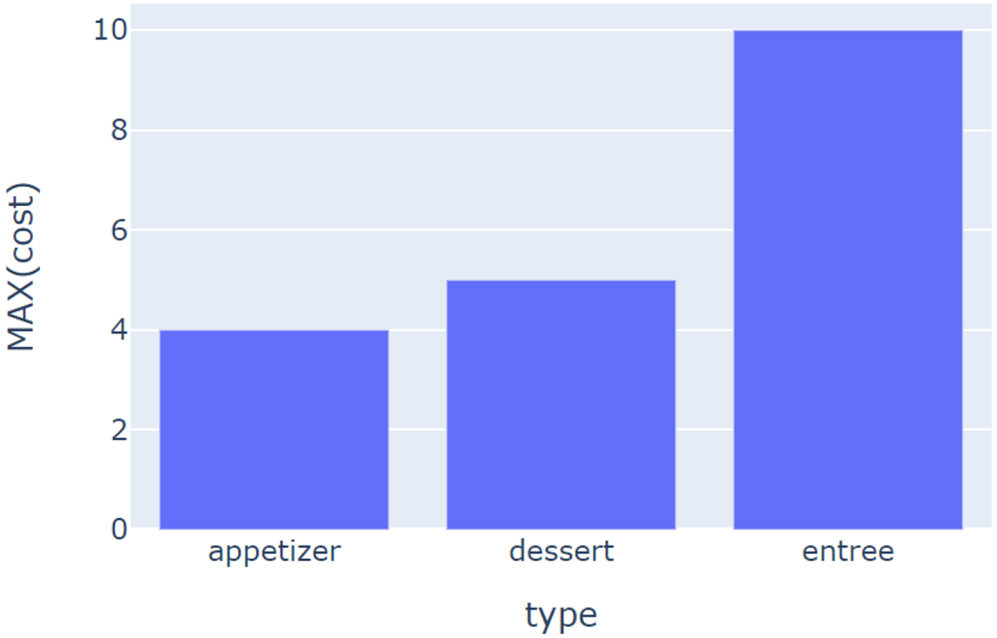
| | type | MAX(cost) |
|---|---|---|
| 0 | appetizer | 4 |
| 1 | dessert | 5 |
| 2 | entree | 10 |

Basic idea:

- First create a `sqlalchemy engine`.
- Then call `engine.connect()` to generate a **`connection`**.
- Then every time you want to make a SQL query, call **`pd.read_sql`**, providing the **SQL code** as the **first argument**, and the **`connection`** as the **second argument**.
- Result of `pd.read_sql` is a DataFrame.

# Example

```
df = pd.read_sql("""
SELECT type, MAX(cost)
FROM Dish
GROUP BY type;""", connection)
px.bar(df, x = "type", y = "MAX(cost)")
```




| | type | MAX(cost) |
|---|---|---|
| 0 | appetizer | 4 |
| 1 | dessert | 5 |
| 2 | entree | 10 |

# LIKE and CAST

- Why Databases
- Warmup: SQL Example
- SQL Tables
- Basic SQL Queries
- Basic GROUP BY Operations
- Trickier GROUP BY Operations
- DISTINCT
- SQL and Pandas
- SQL and Pandas
- **LIKE and CAST**
- SQL Joins

# The IMDB Dataset

IMDB provides a world readable copy of its list of all movies.

- The code below downloads these files, then unzips them.
- The resulting files are stored in tab separated format TSV.
- The titles CSV file is 753 megabytes, too large to be read by pandas on the datahub machines.

```
from os.path import exists

# From https://www.imdb.com/interfaces/
from ds100_utils import fetch_and_cache
data_directory = './data'
fetch_and_cache('https://datasets.imdbws.com/title.basics.tsv.gz',
'titles.tsv.gz', data_directory)
fetch_and_cache('https://datasets.imdbws.com/name.basics.tsv.gz',
'names.tsv.gz', data_directory)
if not exists(f"{data_directory}/titles.tsv"):
    !gunzip -kf {data_directory}/titles.tsv.gz
    !gunzip -kf {data_directory}/names.tsv.gz
```

```
154112110 Mar 31 10:57 titles.tsv.gz
753395433 Mar 31 10:57 titles.tsv
225456571 Mar 31 10:57 names.tsv.gz
689784115 Mar 31 10:57 names.tsv
```

# The IMDB Dataset

The code below (which we will not describe) converts the tsv files into .db format so that SQL can be used instead.

```
from os.path import exists

imdb_file_exists = exists('./data/imdb.db')
if not imdb_file_exists:
    !(cd data; sqlite3 imdb.db ".mode tabs" ".import titles.tsv titles" ".import names.tsv names") 2> /dev/null
```

```
154112110 Mar 31 10:57 titles.tsv.gz
753395433 Mar 31 10:57 titles.tsv
225456571 Mar 31 10:57 names.tsv.gz
689784115 Mar 31 10:57 names.tsv
665415680 Mar 31 11:21 imdb.db
```

# The IMDB Dataset

To read this file in SQL, we create a sqlalchemy connection as before.

```
engine =
sqlalchemy.create_engine("sqlite:///data/imdb.db")
connection = engine.connect()
```

We can then request the list of Tables:

```
tables = pd.read_sql("SELECT sql FROM sqlite_master WHERE type='table';", connection)
tables
```

| | sql |
|---|---|
| 0 | CREATE TABLE "titles"(\n "tconst" TEXT,\n "t... |
| 1 | CREATE TABLE "names"(\n "nconst" TEXT,\n "pr... |

This isn't very readable, so we'll index into the sql column and get rows 0 and 1.

# The IMDB Dataset

The two tables are all movies and all actors, respectively, that IMDB tracks.

```
print(tables["sql"][0])
```

```
CREATE TABLE "titles"(
  "tconst" TEXT,
  "titleType" TEXT,
  "primaryTitle" TEXT,
  "originalTitle" TEXT,
  "isAdult" TEXT,
  "startYear" TEXT,
  "endYear" TEXT,
  "runtimeMinutes" TEXT,
  "genres" TEXT
)
```

```
print(tables["sql"][1])
```

```
CREATE TABLE "names"(
  "nconst" TEXT,
  "primaryName" TEXT,
  "birthYear" TEXT,
  "deathYear" TEXT,
  "primaryProfession" TEXT,
  "knownForTitles" TEXT
)
```

# The IMDB Dataset

The two tables are all movies and all actors, respectively, that IMDB tracks.

```
print(tables["sql"][0])
```

```
CREATE TABLE "titles"(
  "tconst" TEXT,
  "titleType" TEXT,
  "primaryTitle" TEXT,
  "originalTitle" TEXT,
  "isAdult" TEXT,
  "startYear" TEXT,
  "endYear" TEXT,
  "runtimeMinutes" TEXT,
  "genres" TEXT
)
```

```
print(tables["sql"][1])
```

```
CREATE TABLE "names"(
  "nconst" TEXT,
  "primaryName" TEXT,
  "birthYear" TEXT,
  "deathYear" TEXT,
  "primaryProfession" TEXT,
  "knownForTitles" TEXT
)
```

# Getting 10 Rows

```
get_10_movies = """
SELECT *
FROM titles
LIMIT 10
"""

pd.read_sql(get_
```

| | tconst | titleType | primaryTitle | originalTitle | isAdult | startYear | endYear | runtimeMinutes | genres |
|---|---|---|---|---|---|---|---|---|---|
| 0 | tt0000001 | short | Carmencita | Carmencita | 0 | 1894 | \N | 1 | Documentary,Short |
| 1 | tt0000002 | short | Le clown et ses chiens | Le clown et ses chiens | 0 | 1892 | \N | 5 | Animation,Short |
| 2 | tt0000003 | short | Pauvre Pierrot | Pauvre Pierrot | 0 | 1892 | \N | 4 | Animation,Comedy,Romance |
| 3 | tt0000004 | short | Un bon bock | Un bon bock | 0 | 1892 | \N | 12 | Animation,Short |
| 4 | tt0000005 | short | Blacksmith Scene | Blacksmith Scene | 0 | 1893 | \N | 1 | Comedy,Short |
| 5 | tt0000006 | short | Chinese Opium Den | Chinese Opium Den | 0 | 1894 | \N | 1 | Short |
| 6 | tt0000007 | short | Corbett and Courtney Before the Kinetograph | Corbett and Courtney Before the Kinetograph | 0 | 1894 | \N | 1 | Short,Sport |
| 7 | tt0000008 | short | Edison Kinetoscopic Record of a Sneeze | Edison Kinetoscopic Record of a Sneeze | 0 | 1894 | \N | 1 | Documentary,Short |
| 8 | tt0000009 | short | Miss Jerry | Miss Jerry | 0 | 1894 | \N | 40 | Romance,Short |
| 9 | tt0000010 | short | Leaving the Factory | La sortie de l'usine Lumière à Lyon | 0 | 1895 | \N | 1 | Documentary,Short |

# The LIKE Keyword

The LIKE operator tests whether a string matches a pattern (similar to a regex, but much simpler syntax):

- E.g. select rows where the time string is on the hour, such as 8:00 or 12:00 pm.

```
SELECT * FROM t WHERE t.time LIKE ‘%:00%’;
```

# Finding Action Movies

We can use the LIKE keyword to find all Action movies:

```
action_movies_query = f"""
SELECT tconst AS id,
    primaryTitle AS title,
    runtimeMinutes AS time,
    startYear AS year
FROM titles
WHERE titleType = 'movie' AND
    genres LIKE '%Action%'"""


action_movies = pd.read_sql(action_movies_query, connection)
```

# Finding Action Movies

We can use the LIKE keyword to find all Action movies:

```
action_movies_query = f"""
SELECT tconst AS id,
    primaryTitle AS title,
    runtimeMinutes AS time,
    startYear AS year
FROM titles
WHERE titleType = 'movie' AND
    genres LIKE '%Action%'"""


action_movies = pd.read_sql(actio
```

IMDB decided to use "\N" for a missing value.

| | id | title | time | year |
|---|---|---|---|---|
| **0** | tt0000574 | The Story of the Kelly Gang | 70 | 1906 |
| **1** | tt0003545 | Who Will Marry Mary? | \N | 1913 |
| **2** | tt0003747 | Cameo Kirby | 50 | 1914 |
| **3** | tt0003897 | The Exploits of Elaine | 220 | 1914 |
| **4** | tt0004052 | The Hazards of Helen | 1428 | 1914 |
| **...** | ... | ... | ... | ... |

# Three Problems With Our Data

- We see a number of rows containing "\N". These represent values that IMDB was missing.
- Time and year columns are currently given in string format, whereas we probably want them in numeric format.
- Weird outliers like "The Hazards of Helen" which are 1,428 minutes long.

Could fix in pandas, but let's see how to fix in SQL.

| | id | title | time | year |
|---|---|---|---|---|
| **0** | tt0000574 | The Story of the Kelly Gang | 70 | 1906 |
| **1** | tt0003545 | Who Will Marry Mary? | \N | 1913 |
| **2** | tt0003747 | Cameo Kirby | 50 | 1914 |
| **3** | tt0003897 | The Exploits of Elaine | 220 | 1914 |
| **4** | tt0004052 | The Hazards of Helen | 1428 | 1914 |
| **...** | ... | ... | ... | ... |

# CAST

The **CAST** keyword converts a table column to another type.

- In the code below, we convert runtimeMinutes and startYear to int. Any missing invalid values are replaced by 0 (then the WHERE clauses filter out the 0s).

```
action_movies_query = f'''
SELECT tconst AS id,
    primaryTitle AS title,
    CAST(runtimeMinutes AS int) AS time,
    CAST(startYear AS int) AS year
FROM titles
WHERE genres LIKE '%Action%' AND
    titleType = 'movie' AND
    time > 60 AND time < 180 AND
    year > 0
'''

action_movies = pd.read_sql(action_movies_query, connection)
```

# Result of Our Query

```
action_movies_query = f'''
SELECT tconst AS id,
    primaryTitle AS title,
    CAST(runtimeMinutes AS int) AS time,
    CAST(startYear AS int) AS year
FROM titles
WHERE genres LIKE '%Action%' AND
    titleType = 'movie' AND
    time > 60 AND time < 180 AND
    year > 0
'''

action_movies = pd.read_sql(action_movies_query, c
```

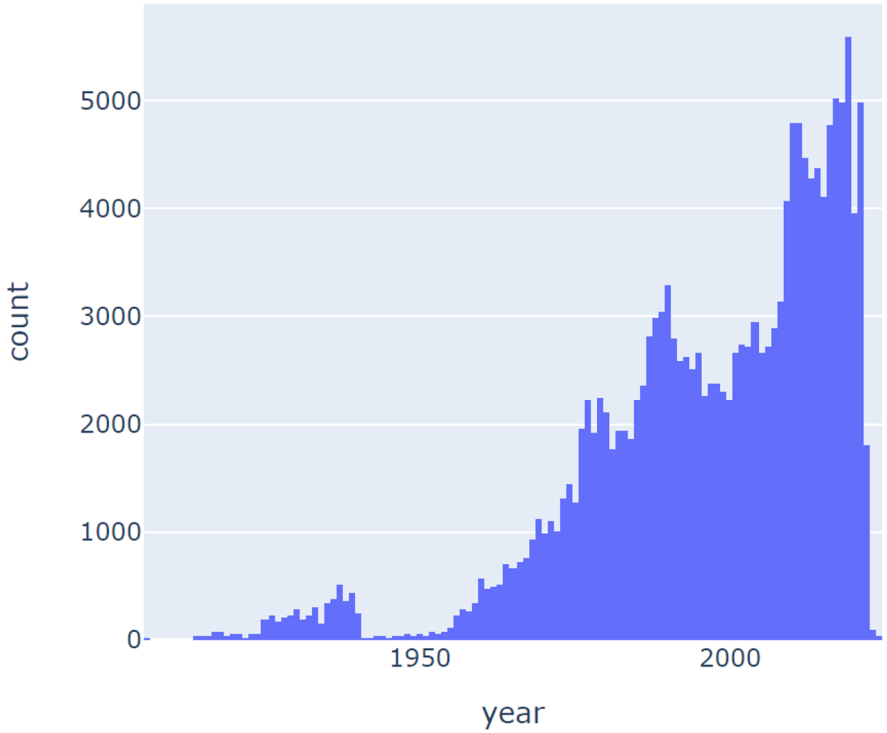
| | id | title | time | year |
|---|---|---|---|---|
| **0** | tt0000574 | The Story of the Kelly Gang | 70 | 1906 |
| **1** | tt0004223 | The Life of General Villa | 105 | 1914 |
| **2** | tt0004450 | Die Pagode | 82 | 1917 |
| **3** | tt0004635 | The Squaw Man | 74 | 1914 |
| **4** | tt0005073 | The Chalice of Courage | 65 | 1915 |
| **...** | ... | ... | ... | ... |
| **164901** | tt9900748 | The Robinsons | 110 | 2019 |
| **164902** | tt9900782 | Kaithi | 145 | 2019 |
| **164903** | tt9900908 | Useless Handcuffs | 89 | 1969 |
| **164904** | tt9901162 | The Robinsons | 90 | 2020 |
| **164905** | tt9904066 | Fox Hunting | 66 | 2019 |

164906 rows × 4 columns

# Visualization

Since we have our data in pandas format, we can use our usual visualization tools:

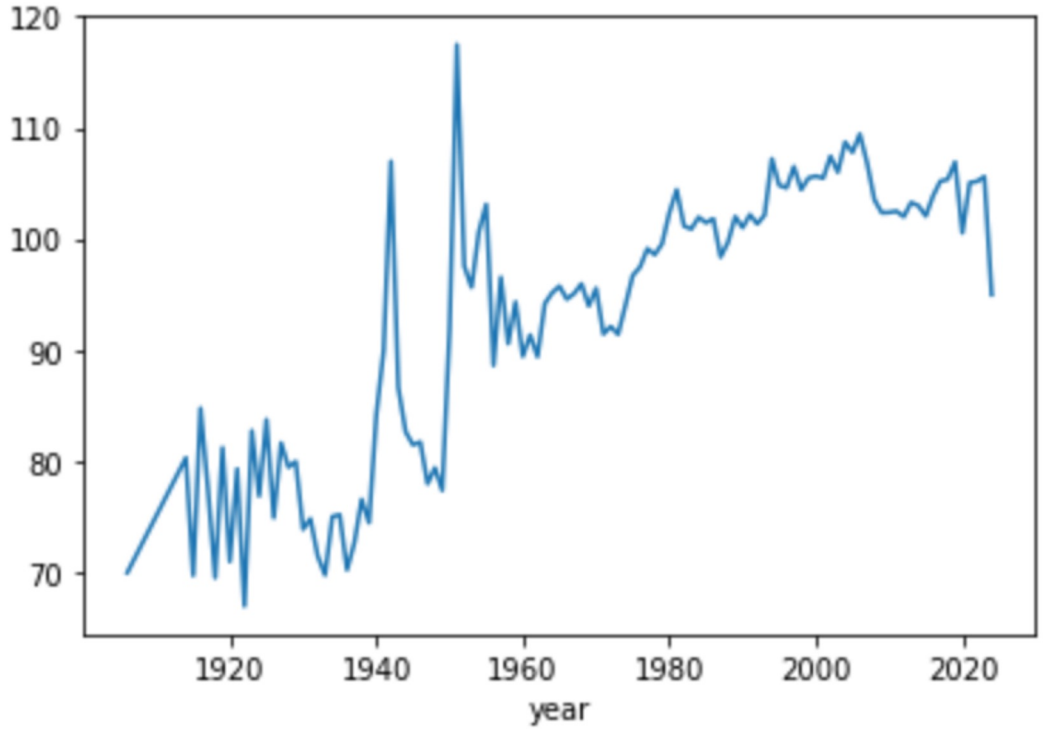
```
px.histogram(action_movies, x = "year")
```



# Visualization

Since we have our data in pandas format, we can use our usual visualization tools:

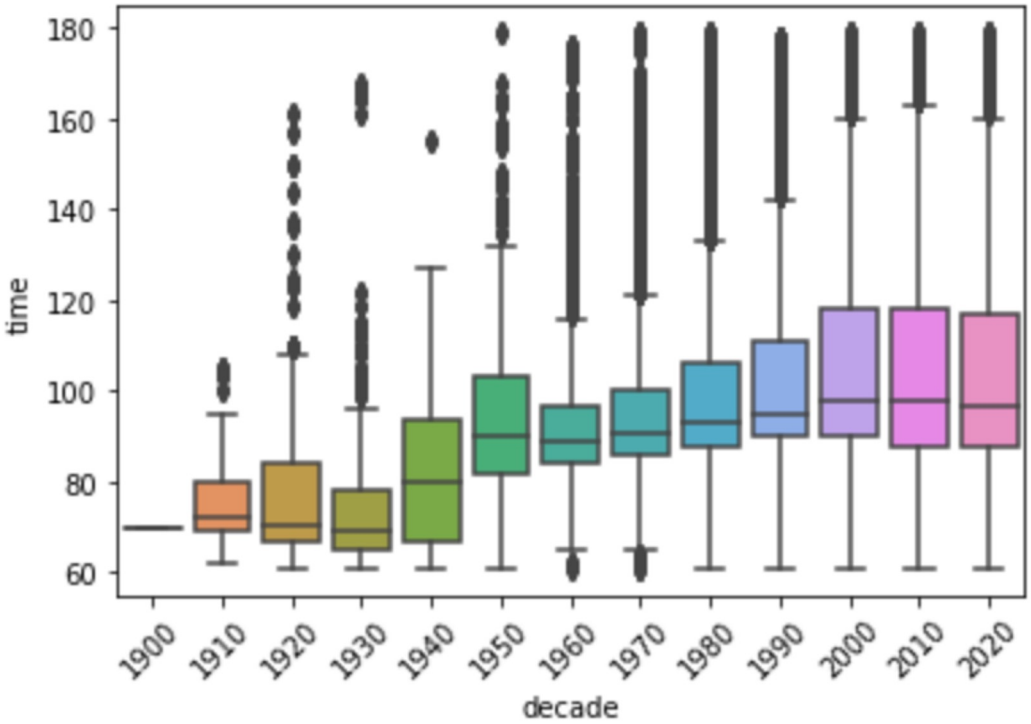
```
action_movies['time'].groupby(action_movies['year']).mean().plot();
```



# Visualization

Since we have our data in pandas format, we can use our usual visualization tools:

```
sns.boxplot(x = 'decade', y = 'time', data = action_movies)
```



# SQL Joins

- Why Databases
- Warmup: SQL Example
- SQL Tables
- Basic SQL Queries
- Basic GROUP BY Operations
- Trickier GROUP BY Operations
- DISTINCT
- SQL and Pandas
- LIKE and CAST
- **SQL Joins**

# Multidimensional Data

## Sales Fact Table

| pid | timeid | locid | sales |
|---|---|---|---|
| 11 | 1 | 1 | 25 |
| 11 | 2 | 1 | 8 |
| 11 | 3 | 1 | 15 |
| 12 | 1 | 1 | 30 |
| 12 | 2 | 1 | 20 |
| 12 | 3 | 1 | 50 |
| 12 | 1 | 1 | 8 |
| 13 | 2 | 1 | 10 |
| 13 | 3 | 1 | 10 |
| 13 | 3 | 2 | 5 |

## Locations

| locid | city | state | country |
|---|---|---|---|
| 1 | Omaha | Nebraska | USA |
| 2 | Seoul | | Korea |
| 5 | Richmond | Virginia | USA |

## Products

| pid | pname | category | price |
|---|---|---|---|
| 11 | Corn | Food | 25 |
| 12 | Galaxy 1 | Phones | 18 |
| 13 | Peanuts | Food | 2 |

## Time

| timeid | Date | Day |
|---|---|---|
| 1 | 3/30/16 | Wed. |
| 2 | 3/31/16 | Thu. |
| 3 | 4/1/16 | Fri. |

Real databases are often stored in a format similar to this shown!

Fact table:

- Minimizes redundant info.
- Reduces data errors.

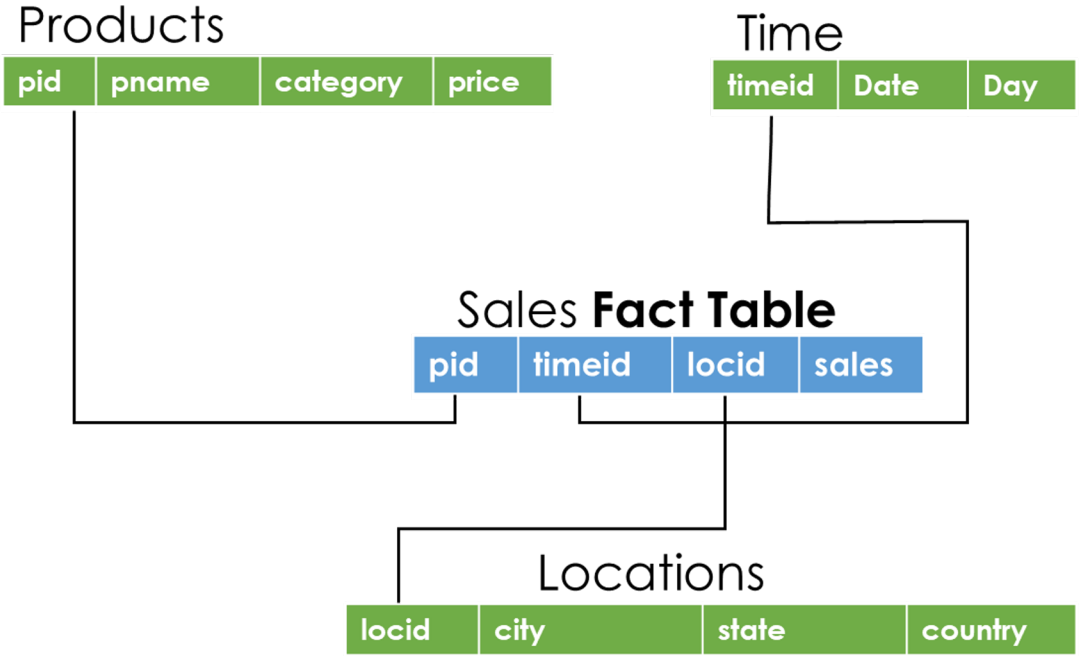
Dimensions:

- Easy to manage and summarize.
- Renaming is easy, just change Galaxy 1 to Phablet.

# Connections Between Tables

To do analysis, we'll need to join our tables!

- Aside: This sort of table organization is often called a "star schema".



# Another Inner Join

An example of a SQL join is shown below:

| Latitude | Longitude | Name |
|---|---|---|
| 34 | 118 | Los Angeles |
| 42 | 71 | Cambridge |
| 45 | 93 | Minneapolis |

| City | Temp |
|---|---|
| Los Angeles | 68 |
| Chicago | 59 |
| Minneapolis | 55 |

```
SELECT name, latitude, temp
FROM cities, temps
WHERE name = city;
```

| Name | Latitude | Temp |
|---|---|---|
| Los Angeles | 118 | 68 |
| Minneapolis | 93 | 55 |

This is an “inner joins”. It turns out there are other types of joins.

# Cross Join

In a cross join, all pairs of rows appear in the result!

- This is also known as the Cartesian product.

s

| id | name |
|---|---|
| 0 | Apricot |
| 1 | Boots |
| 2 | Cally |
| 4 | Eugene |

t

| id | breed |
|---|---|
| 1 | persian |
| 2 | ragdoll |
| 4 | bengal |
| 5 | persian |

```
SELECT * FROM s, t;
```

| s.id | name | t.id | breed |
|---|---|---|---|
| 0 | Apricot | 1 | persian |
| 1 | Boots | 1 | persian |
| 2 | Cally | 1 | persian |
| 4 | Eugene | 1 | persian |
| 0 | Apricot | 2 | ragdoll |
| 1 | Boots | 2 | ragdoll |
| 2 | Cally | 2 | ragdoll |
| 4 | Eugene | 2 | ragdoll |

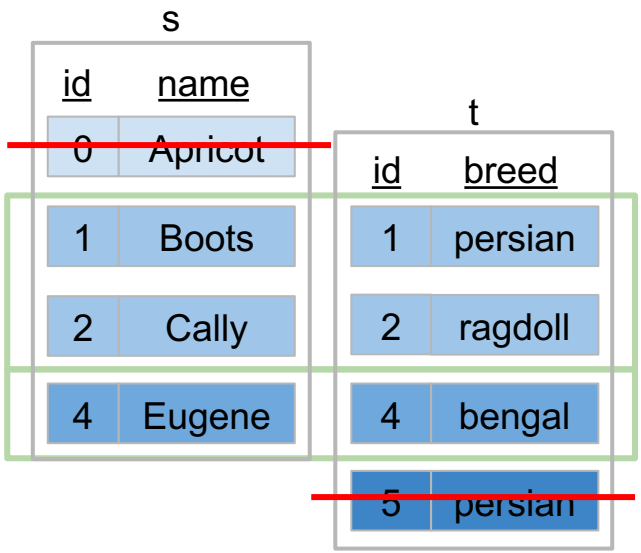
(to be continued …)

(... continued)

| s.id | name | t.id | breed |
|---|---|---|---|
| 0 | Apricot | 4 | bengal |
| 1 | Boots | 4 | bengal |
| 2 | Cally | 4 | bengal |
| 4 | Eugene | 4 | bengal |
| 0 | Apricot | 5 | persian |
| 1 | Boots | 5 | persian |
| 2 | Cally | 5 | persian |
| 4 | Eugene | 5 | persian |

# Inner Join

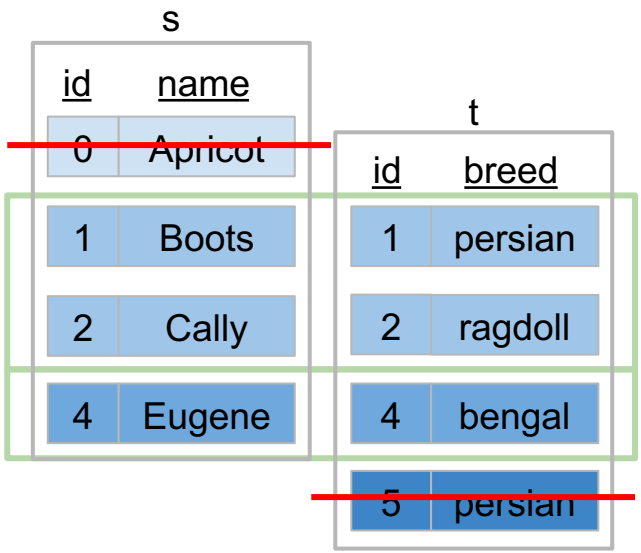
Only pairs of matching rows appear in the result.




```
SELECT * FROM s JOIN t ON s.id = t.id;
SELECT * FROM s INNER JOIN t ON s.id = t.id;
SELECT * FROM s, t WHERE s.id = t.id;
```

# Inner Join

Only pairs of matching rows appear in the result.

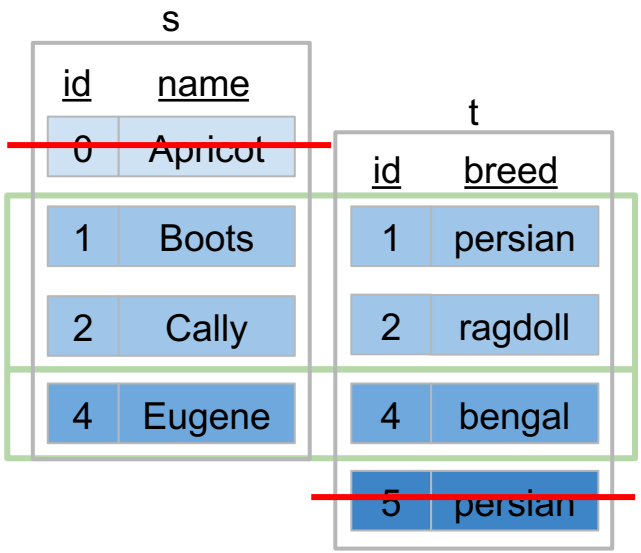



| s.id | name | t.id | breed |
|---|---|---|---|
| 1 | Boots | 1 | persian |
| 2 | Cally | 2 | ragdoll |
| 4 | Eugene | 4 | bengal |

```
SELECT * FROM s JOIN t ON s.id = t.id;
SELECT * FROM s INNER JOIN t ON s.id = t.id;
SELECT * FROM s, t WHERE s.id = t.id;
```

# Relationship Between Cross Joins and Inner Join

Conceptually, an inner join is a cross join followed by removal of bad rows.




| s.id | name | t.id | breed |
|---|---|---|---|
| 0 | Apricot | 1 | persian |
| 1 | Boots | 1 | persian |
| 2 | Cally | 1 | persian |
| 4 | Eugene | 1 | persian |
| 0 | Apricot | 2 | ragdoll |
| 1 | Boots | 2 | ragdoll |
| 2 | Cally | 2 | ragdoll |
| 4 | Eugene | 2 | ragdoll |

(to be continued …)

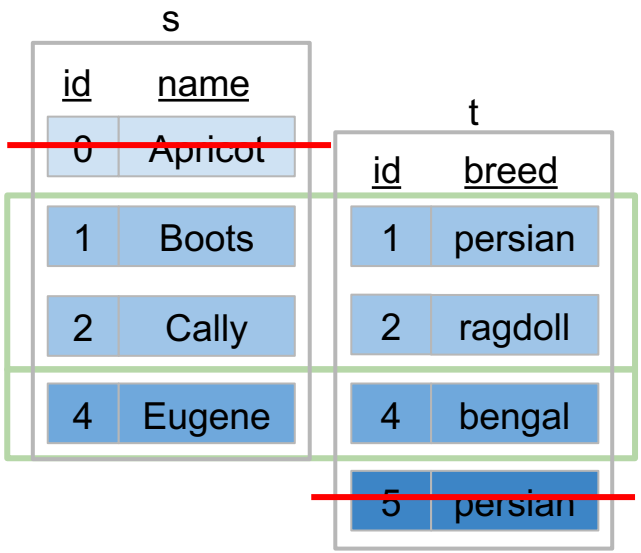
(... continued)

| s.id | name | t.id | breed |
|---|---|---|---|
| 0 | Apricot | 4 | bengal |
| 1 | Boots | 4 | bengal |
| 2 | Cally | 4 | bengal |
| 4 | Eugene | 4 | bengal |
| 0 | Apricot | 5 | persian |
| 1 | Boots | 5 | persian |
| 2 | Cally | 5 | persian |
| 4 | Eugene | 5 | persian |

```
SELECT * FROM s, t WHERE s.id = t.id;
```

# Relationship Between Cross Joins and Inner Join

Conceptually, an inner join is a cross join followed by removal of bad rows.

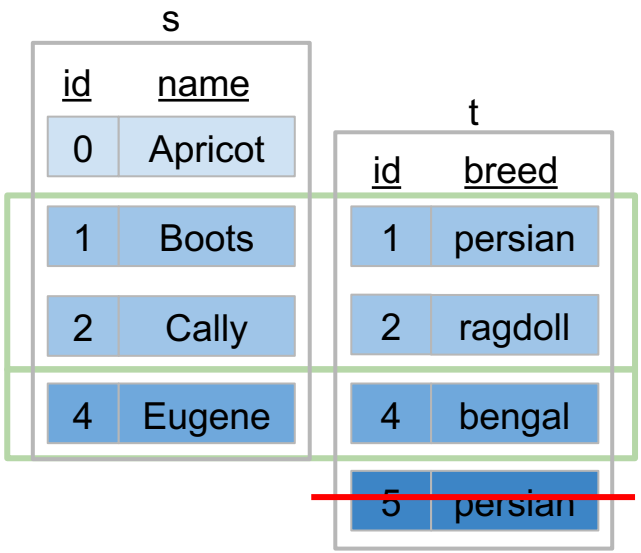



| s.id | name | t.id | breed |
|---|---|---|---|
| 1 | Boots | 1 | persian |
| 2 | Cally | 2 | ragdoll |
| 4 | Eugene | 4 | bengal |

```
SELECT * FROM s, t WHERE s.id = t.id;
```

# Left Outer Join

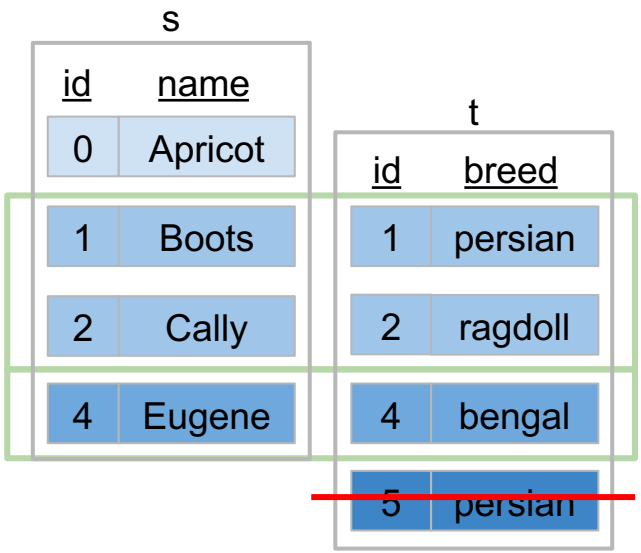
Every row in the first table appears in the result, matching or not.




```
SELECT * FROM s LEFT JOIN t ON s.u = t.v;
```

# Left Outer Join

Every row in the first table appears in the result, matching or not.




| s.id | name | t.id | breed |
|---|---|---|---|
| 0 | Apricot | | |
| 1 | Boots | 1 | persian |
| 2 | Cally | 2 | ragdoll |
| 4 | Eugene | 4 | bengal |

Missing values are null.

```
SELECT * FROM s LEFT JOIN t ON s.u = t.v;
```

# Right Outer Join

Every row in the second table appears in the result, matching or not.

s

| id | name |
|---|---|
| 0 | Apricot |
| 1 | Boots |
| 2 | Cally |
| 4 | Eugene |

t

| id | breed |
|---|---|
| 1 | persian |
| 2 | ragdoll |
| 4 | bengal |
| 5 | persian |

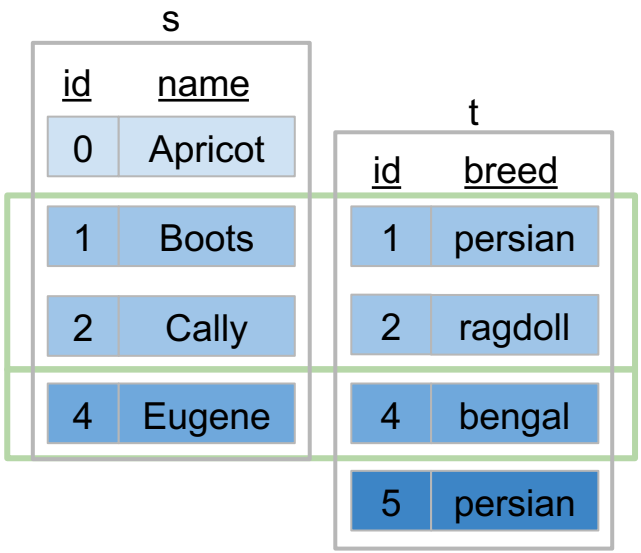
| s.id | name | t.id | breed |
|---|---|---|---|
| 1 | Boots | 1 | persian |
| 2 | Cally | 2 | ragdoll |
| 4 | Eugene | 4 | bengal |
| | | 5 | persian |

```
SELECT * FROM s RIGHT JOIN t ON s.u = t.v;
```

Note: SQLite does not implement RIGHT JOIN.

# Full Outer Join

Every row in both tables appears, matching or not.




| s.id | name | t.id | breed |
|---|---|---|---|
| 0 | Apricot | | |
| 1 | Boots | 1 | persian |
| 2 | Cally | 2 | ragdoll |
| 4 | Eugene | 4 | bengal |
| | | 5 | persian |

```
SELECT * FROM s FULL OUTER JOIN t ON s.u = t.v;
```

Note: SQLite does not support FULL OUTER JOIN.

# Other Join Conditions

We can join on conditions other than equality.

student

| age | name |
|---|---|
| 29 | Jameel |
| 37 | Jian |
| 20 | John |
| 20 | Emma |

teacher

| age | breed |
|---|---|
| 52 | Ira |
| 41 | Husain |
| 27 | John |
| 36 | Anuja |

```
SELECT * FROM student, teacher WHERE student.age > teacher.age;
```

# Other Join Conditions

We can join on conditions other than equality.

student

| age | name |
|---|---|
| 29 | Jameel |
| 37 | Jian |
| 20 | John |
| 20 | Emma |

teacher

| age | breed |
|---|---|
| 52 | Ira |
| 41 | Husain |
| 27 | John |
| 36 | Anuja |

| | | | |
|---|---|---|---|
| 29 | Jameel | 27 | John |
| 37 | Jian | 27 | John |
| 37 | Jian | 36 | Anuja |

Note that every satisfying pair appears.

- Inner joins are just cross joins followed by removing rows that don't match.

```
SELECT * FROM student, teacher WHERE student.age > teacher.age;
```

# SQL and Databases Summary

Databases are a more sophisticated way to store data than simple CSV or similar files.

For DS purposes the advantages are:

- Ability to interact with large datasets.
- Ability to harness SQL syntax, which can be simpler in some situations. Examples:
  - Applying multiple aggregation functions.
  - Joins