Week 02: SQL

Data Science Bootcamp
Summer, 2021

Instructor: Sagar Patel

Where are we?

Week 1 — Week 2 — Week 3 — Week 4 — Week 5 — Week 6

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Introduction	**SQL**	**Python libraries**	**Exploratory Data Analysis**	**Machine Learning**	**Project & Wrap**
Introduction to Python; Getting started with Git and GitHub					

Communities

- Join the **Slack** community to not miss out on any announcements and updates
  Link: https://join.slack.com/t/nyu-dsbc-s21/shared_invite/zt-reskrjo0-eCwFfCmnVYnTAc82lTVNJw
- Share your **GitHub** Username on **#general** to be added to the NYU Data Science Bootcamp Organization where all the resources and tasks will be available after each session
  - If you do not have a GitHub account, create one!
- You can also email us at **datasciencebootcamp@nyu.edu**

Agenda

- Database Management Systems
  - Relational Databases
- Structured Query Language (SQL)
  - **SELECT**ing, **JOIN**ing, and modifying data
  - Aggregations
  - Indexing

NOTE: Database research is a huge topic!

This intro will be brief and cursory.

Database

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Have you worked with Databases before?

ⓘ Start presenting to display the poll results on this slide.

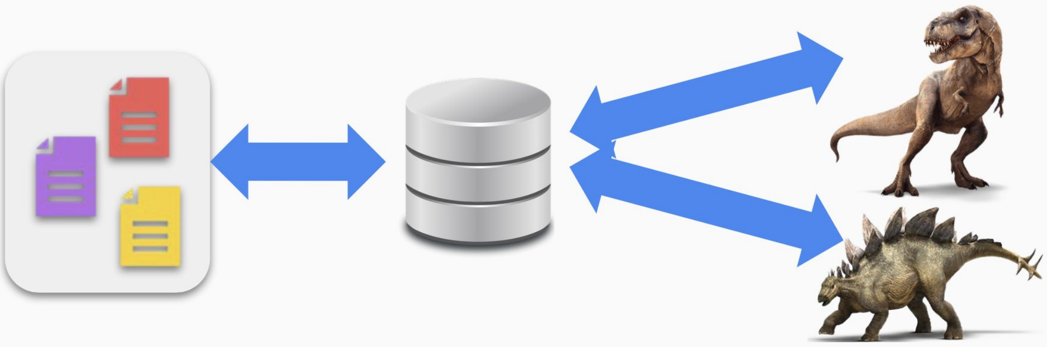
What is a Database?

- An **organized collection** of structured information, or data, typically stored electronically in a computer system.
- What happens if the information is stored on **cloud**? Is that a database?
  - **Yes**, it is.
  - The information stored is still an organized collection, even if it is not stored in the same computer system.

Database management systems (DBMS)

- DBMS's job is to provide
  - Data integrity / consistency
  - Concurrent access
  - Efficient storage and access
  - Standardized format / administration
  - Standardized query interface (language)

- DBMS come in many flavors
  - **Relational (RDBMS)**
  - Semi-structured (e.g., XML)
  - Object-oriented
  - Object-relational
  - ...



The relational model

- **High-level**: tables of data that you are probably used to
  - Spreadsheets, dataframes, numerical arrays, etc.
- Each column represents a **set** of possible values (numbers, strings, etc.)

The relational model

- **High-level**: tables of data that you are probably used to
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- A ***relation*** over sets $A_1, A_2, A_3, \ldots, A_n$ is a **subset** of their cartesian product
  - $R \subseteq A_1 \times A_2 \times A_3 \times \ldots \times A_n$
  - The **rows** of the table are elements of **R**, also known as ***tuples***
  - $(a_1, a_2, \ldots, a_n) \in R \Rightarrow a_1 \in A_1, a_2 \in A_2, \ldots, a_n \in A_n$

Example: dinosaurs

- A_1 = {s | s is a **string**}
  A_2 = {“Jurassic”, “Cretaceous”, “Devonian”, “Triassic”, ...}
  A_3 = {“Carnivore”, “Herbivore”, “Omnivore”, ...}
  A_4 = {False, True}
- Any A_i could be finite or infinite
- $R \subseteq A_1 \times A_2 \times A_3 \times A_4$ need not contain all combinations!

Species	Era	Diet	Awesome
T. Rex	Cretaceous	Carnivore	True
Stegosaurus	Jurassic	Herbivore	True
Ankylosaurus	Cretaceous	Herbivore	False

Aside: Why “relations” and not “tables”?

- Relations are the abstract model of data
- **Table** refers to an **explicitly** constructed relation
  - i.e., records you have observed / collected
- Other relations in a database:
  - **View**: A relation defined **implicitly**, and constructed **dynamically** at run-time
  - **Temporary table**: the output of a **query**

Properties of relations

- **R** $\subseteq$ $A_1 \times A_2 \times A_3 \times \ldots \times A_n$ is a set
  - The tuples (rows) of **R** are **unordered**
  - Tuples are **unique** ⇒ no duplicates!
  - Relations over common domains (columns) can be combined by set operations

Species	Era	Diet	Awesome
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Properties of relations

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  - Relations over common domains (columns) can be combined by set operations
- In practice, add a column (e.g., A_0) with **identifiers** to force uniqueness
  - This is not (usually) part of the data, but is generated automatically by the DBMS
  - ID fields are often used as **primary keys**, and give a default order to rows

id	Species	Era	Diet	Awesome
1	T. Rex	Cretaceous	Carnivore	True
2	Stegosaurus	Jurassic	Herbivore	True
3	Ankylosaurus	Cretaceous	Herbivore	False

Schemas

id	Species	Era	Diet	Awesome
1	T. Rex	Cretaceous	Carnivore	True
2	Stegosaurus	Jurassic	Herbivore	True
3	Ankylosaurus	Cretaceous	Herbivore	False
4	Homer	Boomer	Donuts	False

- A relation is defined by a **schema**:

Dinosaur(id: int, Species: string, Era: string, Diet: string, Awesome: boolean)

- **Any** tuple (int, string, string, string, boolean) is valid under this schema
  - Schemas enforce type (syntax), but not semantics!

Relational databases

- A relational database consists of one or more relational schemas
- Structured data can be encoded by **joining** on **shared attributes**
- The collection of schemas defines your **data model**

id	Species	Era	Diet	Awesome
1	T. Rex	Cretaceous	Carnivore	True
2	Stegosaurus	Jurassic	Herbivore	True
3	Ankylosaurus	Cretaceous	Herbivore	False

id	Name	Species	Internals
1	Earl Sinclair	Megalosaurus	Puppet
2	Grimlock	T. Rex	Robot
3	Snarl	Stegosaurus	Robot

Keys

id	First Name	Last Name	Age
1	Homer	Simpson	39
2	Marge	Simpson	39
3	Bart	Simpson	10
4	Homer	Thompson	39
5	Homer	Simpson	28

- Keys are what determine the **identity** of a row
- Keys can be **simple** (single column) or **compound** (two or more columns)
  - Example: **(First Name, Last Name)**
  - This prevents two rows with the same combination of first and last name

- You can have **primary** and **alternate keys**
  - Usually a good idea to keep a primary numeric key as well as others you may want...

Foreign Keys

id	Species	Era	Diet	Awesome
1	T. Rex	Cretaceous	Carnivore	True
2	Stegosaurus	Jurassic	Herbivore	True
3	Ankylosaurus	Cretaceous	Herbivore	False

id	Name	DinosaurID	Internals
1	Earl Sinclair	25	Puppet
2	Grimlock	1	Robot
3	Snarl	3	Robot

- A **key** from one relation can be a **column** in another
  - This is called a **FOREIGN KEY** constraint
- This can be used to ensure reference consistency **between** tables/relations
- **This is not automatic**: must be included in the **schema** definition!

SQL

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Do you have any experience working with SQL?

ⓘ Start presenting to display the poll results on this slide.

Structured Query Language

- SQL is the language we use to talk to databases
  - Not a procedural language like Python or C
  - **Declarative**: state what you want, not how to compute it
- Think of it more like a **protocol** than a programming language
- SQL is an ANSI standard, but different implementations each have quirks
  - **MySQL** vs. **Postgres** vs. **SQLite** vs. **MSSQL** ...

Using CREATE

- While working with an SQL server on local computer:

```
CREATE DATABASE [Name];
SHOW DATABASES;
USE [Name];
```

- Creating a table:

```
CREATE TABLE    Dinosaur (
                id          INT AUTO INCREMENT,
                Species     VARCHAR(20),
                …,
                PRIMARY KEY (id)
);
```

SELECTing data

- Get all rows: **SELECT** * **FROM** Dinosaur

id	Species	Era	Diet	Awesome
1	T. Rex	Cretaceous	Carnivore	True
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SELECTing data

- Get all rows: **SELECT** * **FROM** Dinosaur
- Get some rows: **SELECT** * **FROM** Dinosaur **WHERE** Awesome = True

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SELECTing data

- Get all rows: **SELECT** * **FROM** Dinosaur
- Get some rows: **SELECT** * **FROM** Dinosaur
  WHERE Awesome = True

- Get columns: **SELECT** Era, Species
  FROM Dinosaur
  WHERE id>2

id	Species	Era	Diet	Awesome
1	T. Rex	Cretaceous	Carnivore	True
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Era	Species
Cretaceous	Ankylosaurus
Boomer	Homer

Selection

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- Remove tuples by filtering (**WHERE** ...)
- And remove / rename / reorder columns

- Result of **SELECT** is always another relation

JOINing relations

- Data is typically structured across multiple relations
- We can combine relations by **JOIN**ing

- **SELECT** * **FROM** Dinosaur **JOIN** Character

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A [?] JOIN B

Least specific

Most specific

CROSS JOIN	**All combination** of rows (r_1, r_2) $r_1 \in A$, $r_2 \in B \Rightarrow A \times B$ (no matching condition)
[LEFT/RIGHT/FULL] OUTER JOIN	**All rows are retained** from **A** (**LEFT**) or **B** (**RIGHT**), even if no match is found. Fill missing data with **NULL**
INNER JOIN	**Only matching rows** are retained (Like **OUTER** but without NULLs)
NATURAL JOIN	Rows must match on **all shared columns** (Special case of **INNER**)

A [?] JOIN B

INNER and **OUTER** joins are most common

Least specific

Most specific

CROSS JOIN	**All combination** of rows (r_1, r_2) $r_1 \in A, r_2 \in B \Rightarrow A \times B$ (no matching condition)
[LEFT/RIGHT/FULL] OUTER JOIN	**All rows are retained** from **A** (**LEFT**) or **B** (**RIGHT**), even if no match is found. Fill missing data with **NULL**
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Modifying data

```
INSERT INTO table (column1, column2, …)
VALUES      (value1, value2, …),
            [(row_2_value1, row_2_value2, ...), …]
```

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

Aggregation queries

id	Name	Height	Street	Zip
1	T. Rex	3.66	5th Ave.	10003
2	Stegosaurus	2	8th St.	10004
3	Ankylosaurus	1.7	Lafayette St.	10003

- Aggregation lets us summarize multiple tuples into a single result

- Example: find the average height of people within a ZIP code
  SELECT Zip, AVG(Height) **FROM** Residents **GROUP BY** Zip

Zip	AVG(Height)
10003	2.68
10004	2

Some useful aggregators

- **AVG, SUM, MIN, MAX** ⇐ what you expect
- **COUNT(DISTINCT** x) ⇐ # of unique values of column x
- **COUNT**(*) vs **COUNT**(x) ⇐ # rows vs # non-nulls of a column
- **GROUP_CONCAT**(x) ⇐ concatenate (string) values
  GROUP_CONCAT(x, y) ⇐ same, but join with string y

Aggregation conditions

- **SELECT** … **WHERE** [condition] **GROUP BY** [fields]
- **WHERE** clause applies to input, not output
- What if you only want to keep certain groups (e.g., sum > 10)?
  - ... **HAVING** [group condition]

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- **WHERE** clause applies to input, not output
- What if you only want to keep certain groups (e.g., sum > 10)?
    - ... **HAVING** [group condition]
    - **SELECT** sum(Height) **FROM** TallDinos **GROUP BY** Zip **HAVING** sum(Height) > 10

Indexing

id	Name	Country	Street	Zip
1	T. Rex	US	5th Ave.	10003
2	Stegosaurus	US	8th St.	10004
3	Ankylosaurus	CA	Spadina Ave.	M5T 3A5

- An **index** is a data structure over one or more columns that can accelerate queries
- Example:
  - A table that has few distinct values repeated millions of times
  - And you frequently want all rows with exactly one given value
  - It might be faster to store mapping values → rows
    than to search each row independently

When to index?

- When data is **read more often** than written
- When queries are **predictable**
- When queries rely on a **small number of attributes**
- **Remember**: you can always add or delete indices later

Summary

- We use relational data everyday without thinking of it
- Database consist of one or more relations
- Schemas provide some degree of safety and validation
- SQL provides a standard interface to relational databases
- Use indices to organize your data ahead of time

That’s all Folks!

See you in the next session :)

Give us a feedback: https://bit.ly/3g6ZDlD