Lecture 01:Introduction to Data Management with SQL

DATA 351: Data Management with SQL

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This lecture covers the introduction to data management with SQL.

Table of contents

1 Motivations

1.1 Data Science and Data

Data science is fundamentally tied to the data that it analyzes.

Before any analysis can be done, we need to know:

- In what way we want to store the data
- How we want to organize the data with that storage
- How we can easily retrieve the desired data when we need it

1.2 Requirements for Data Storage

All data storage solutions need to be:

Reliable If a hard drive goes corrupt, we cannot just lose all of our data.

Scalable We may need ways for thousands of individuals across the world to access at the same time.

Maintainable The needs of an organization or the data itself can shift over time. The storage needs to be flexible enough to handle these shifts.

This is the work of a **data engineer**.

2 Why a Database?

2.1 Data Storage Options

There are many different ways information can be stored, with varying trade-offs.

Suppose you wanted to keep track of your friends' birthdays:

Figure 1: Friends

First Name	Last Name	Birthday
Eleven	Hopper	4/2/2004
Dustin	Henderson	8/23/2003
Max	Mayfield	12/14/2005

2.2 Option 1: Tables (CSV)

You could store the information in a table or comma-separated values (CSV) file:

First Name	Last Name	Birthday
Eleven	Hopper	4/2/2004
Dustin	Henderson	8/23/2003
Max	Mayfield	12/14/2005

```
First Name,Last Name,Birthday
Eleven,Hopper,4/2/2004
```

```
Dustin,Henderson,8/23/2003
Max,Mayfield,12/14/2005
```

2.3 Option 2: JSON

Alternatively, you might use some other form of common data structure like JSON:

```
[
  {"First Name": "Eleven",
   "Last Name": "Hopper",
   "Birthday": "4/2/2004"},
  {"First Name": "Dustin",
   "Last Name": "Henderson",
   "Birthday": "8/23/2003"},
  {"First Name": "Max",
   "Last Name": "Mayfield",
   "Birthday": "12/14/2005"}
]
```

2.4 The Plot Thickens

Suppose now you would also like to keep track of what courses they are currently taking at Hawkins High, and what times those courses are held.

Suppose each friend is taking 2-3 classes, some of which overlap.

This significantly complicates both storage methods.

2.5 Table Storage Problem

We cannot store tables inside of tables, so we usually need to duplicate information over multiple rows:

First Name	Last Name	Birthday	Class	Day	Time
Eleven	Hopper	4/2/2004	CHEM101	MWF	1:00pm
Eleven	Hopper	4/2/2004	AV101	MWF	9:00am
Dustin	Henderson	8/23/2003	CHEM101	MWF	1:00pm
Dustin	Henderson	8/23/2003	PHYS201	TTh	1:00pm

Duplication is generally bad!

2.6 JSON Storage Problem

We still have duplication issues with JSON as well:

```
[
  {"First Name": "Eleven", "Last Name": "Hopper",
   "Birthday": "4/2/2004",
   "Classes": [
     {"class": "CHEM101", "day": "MWF", "time":"1:00pm"},
     {"class": "AV101", "day": "MWF", "time":"9:00am"}
   ]},
  {"First Name": "Dustin", "Last Name": "Henderson",
   "Birthday": "8/23/2003",
   "Classes": [
     {"class": "CHEM101", "day": "MWF", "time":"1:00pm"},
     {"class": "PHYS201", "day": "TTh", "time":"1:00pm"}
   ]}
]
```

Class information like day and time is duplicated across friends.

3 Relational Databases

3.1 The Relational Solution

One solution is realizing that we are trying to actually keep track of two things: friends and classes.

So we break things up into two tables, and then create relationships between them.

This is the core of what occurs in a **relational database**.

3.2 Separate Tables

Friends Table:

First Name	Last Name	Birthday
Eleven	Hopper	4/2/2004
Dustin	Henderson	8/23/2003
Max	Mayfield	12/14/2005

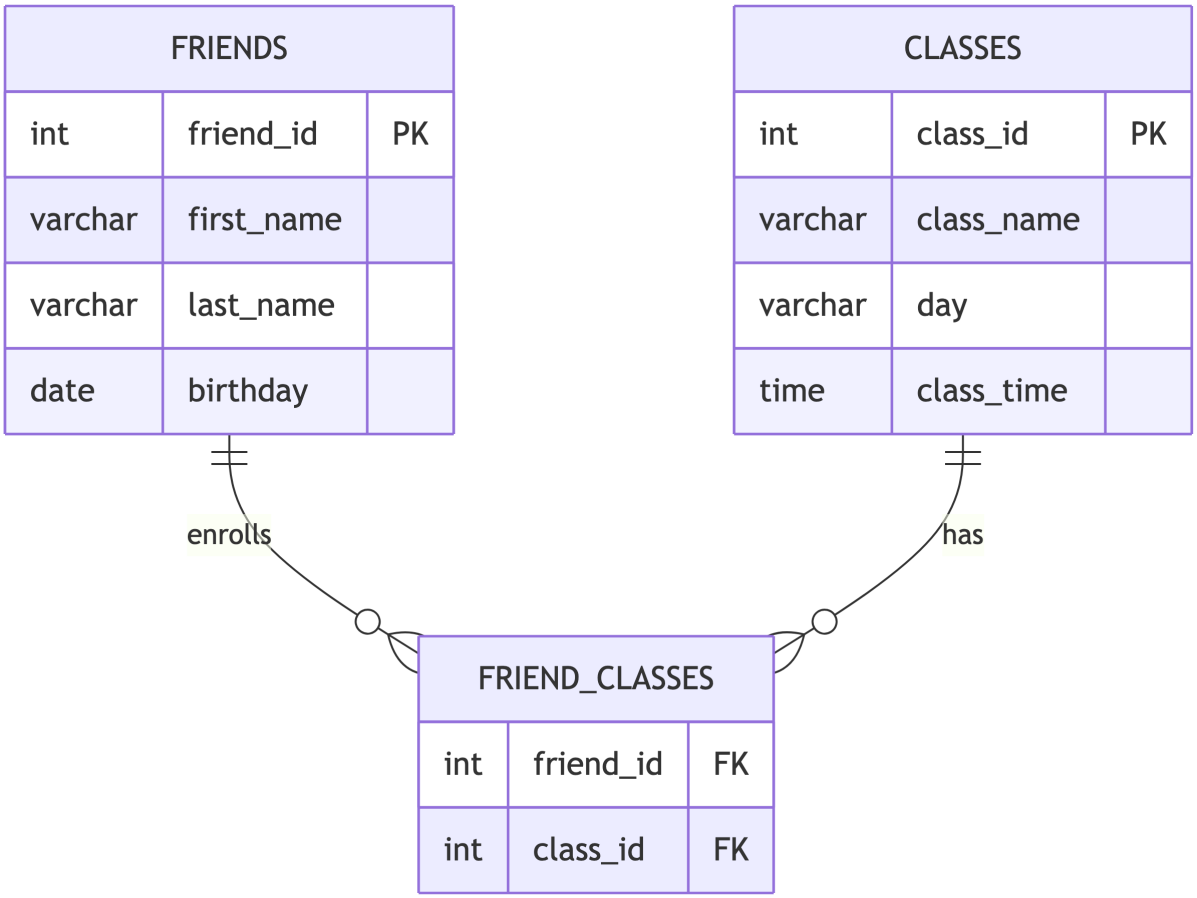
Classes Table:

Class	Day	Time
CHEM101	MWF	1:00pm
AV101	MWF	9:00am
PHYS201	TTh	1:00pm
HIST150	MWF	12:00pm

3.3 Linking Tables with Relationships

In general, you would use a third table to represent all the linkages.

Unique ID keys are used to connect the different tables.



3.4 Benefits of Relational Databases

- **No duplication**: Each piece of information is stored once
- **Data integrity**: Changes only need to be made in one place
- **Flexibility**: Easy to add new relationships without restructuring
- **Efficient queries**: Can retrieve complex related data quickly

3.5 Quick Note on Data Types

In a relational database we can specify what type of information is allowed in each column:

- `int` for integers
- `varchar` for text
- `date` for dates
- `time` for times
- `boolean` for true/false values
- `numeric` for decimal numbers

This keeps information consistent and predictable.

4 SQL Overview

4.1 What is SQL?

SQL is a language that allows you to define and query relational databases.

Pronunciation:

- Modern: "ESS-CUE-ELL"
- Historical: "SEQUEL" (Structured English Query Language, renamed due to trademark issues)

SQL is often called "Structured Query Language," ***but*** the name is misleading:

- **Not "structured"**: SQL is declarative (you say what you want, not how to get it)
- **Not just "query"**: SQL also creates tables, inserts data, and manages permissions
- **Not a full "language"**: Standard SQL is not Turing complete

4.2 SQL Variants

SQL comes in several variants, though the core standards are governed by ANSI and ISO, so none stray too far from the standards.

Common SQL variants include:

- **PostgreSQL** (our focus this semester)
- MySQL / MariaDB
- SQLite
- Microsoft SQL Server
- Oracle Database

Skills transfer easily between variants.

5 PostgreSQL Basics

5.1 SQL Servers

PostgreSQL operates on a server model where clients contact the server and ask it to manipulate or query a particular database.

- Multiple databases can exist on the server at a time
- Works well for large distributions
- You can also run a local server on your computer

5.2 Interacting with PostgreSQL

Several ways you can interact with the server:

- **Terminal prompt** (psql command line)
- **pgAdmin** (as detailed in the textbook)
- **Beekeeper Studio** (Community Edition)

We will use Beekeeper Studio or pgAdmin in this course.

5.3 Creating a New Database

SQL has commands to help with administration as well as creating, manipulating, and querying tables.

New installs come with a database called `postgres`, but it is good practice to create a new one and leave the default untouched.

```
CREATE DATABASE hawkins_high;
```

5.4 Creating a New Table

Creating tables is one of the more fundamental actions you may need to take with a database.

Need to specify:

- The name of the table
- The names of the columns and their data types

```
CREATE TABLE table_name (
    column_name1 type1,
    column_name2 type2,
    column_name3 type3
);
```

5.5 SQL Syntax Conventions

SQL requires no special formatting for capitalization or tabbing, but conventions help readability:

- Use UPPERCASE for SQL keywords
- Use lowercase and underscores for table or column names
- Indent clauses and blocks of code for readability
- A semicolon indicates the end of a command
- Text and dates need single quotes, numbers do not

5.6 Example: Creating a Friends Table

```
CREATE TABLE friends (
    friend_id int,
    first_name varchar(50),
    last_name varchar(50),
    birthday date
);
```

5.7 Adding Values to a Table

Tables are initially empty. You add data by inserting new values into the columns.

```
INSERT INTO friends (friend_id, first_name, last_name, birthday)
VALUES (1, 'Eleven', 'Hopper', '2004-04-02'),
       (2, 'Dustin', 'Henderson', '2003-08-23'),
       (3, 'Max', 'Mayfield', '2005-12-14');
```

New rows are concatenated to the end of the table.

5.8 Querying Data

Once data is in the table, you can retrieve it using SELECT:

```
SELECT first_name, last_name, birthday
FROM friends;
```

first_name	last_name	birthday
Eleven	Hopper	2004-04-02
Dustin	Henderson	2003-08-23
Max	Mayfield	2005-12-14

6 Summary

6.1 Key Takeaways

Data Management Fundamentals:

- Data storage must be reliable, scalable, and maintainable
- Flat files (CSV, JSON) lead to data duplication problems

- Relational databases solve duplication through linked tables

SQL Basics:

- SQL is the language for defining and querying relational databases
- PostgreSQL is our SQL variant of choice
- Tables have columns with defined data types
- Data is added with INSERT and retrieved with SELECT

6.2 What is Next

Reading: Chapter 1 and Chapter 2 of Practical SQL

Topics:

- Setting up your PostgreSQL environment
- Using SELECT to query data
- Filtering and sorting results