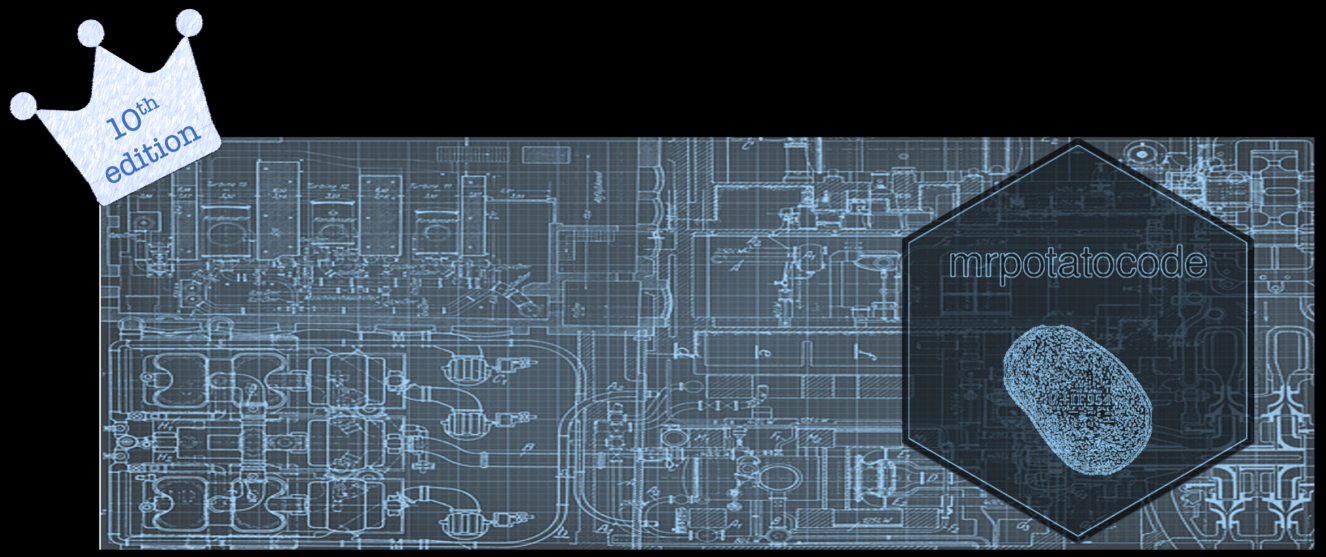

Introduction to Data Access and Storage

Thomas Rosenthal - DSI @ UofT

Session 01

Introduction:

Welcome

What is SQL?

Data Modelling

Introduction:

Welcome

What is SQL?

Data Modelling

Welcome

About Us

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Quick Technical Check

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About Us

Course Content

Quick Technical Check

About Us (Thomas)

- Fell into SQL in my first job out of undergraduate
- Worked as a Data Analyst in US healthcare until moving to Canada in 2018
  - Challenging data
  - Easy to see impact of good queries
  - I was pretty naive about data, probably lucky I didn't break anything 🤦
- Worked as a Data Engineer at Plan Canada managing a CRM Data Warehouse backend
- Went back to UofT to do my Master of Information
  - Wanted to do less SQL, more R and python
  - SQL seemed like it was on its way out...NOPE, I was just wrong
- Reluctant Data Scientist (*do we even need this model?*)
  - Currently doing AI Governance and Ethics implementation at Dataiku
- Have a 4 year old Samoyed named Alto who takes up a lot of my free time 👉

About Us (Edward)

- Graduated from the Master of Science in Applied Computing program at UofT
- Currently working as a Research Analyst at the University Health Network
- Will start PhD in Medical Biophysics at UofT in September
- Have worked on creating course material for data science and machine learning at UofT
- Hobbies: Gaming, Crochet, Archery

About Us (Moniz)

- Master in Biomedical Engineering 🎓
- Project and Data Coordinator in Healthcare setting 🏥
- DSI cohort 3 📈
- Hobbies: camping ⛺ travelling ✈ and see the world

About Us (Niyaz)

- Master's in Artificial Intelligence with a deep understanding of machine learning algorithms, data science, and advanced computational techniques
- 15 years of experience in software development, database design, and query optimization
- DSI cohort 2
- Co-founder of a company offering web design, SEO, and Google Ads services in Canada
- Experienced mentor and facilitator in product development, focusing on code reviews and Agile practices to ensure quality and continuous improvement
- I always enjoy helping others learn while continuously learning myself

Welcome

About Us

Course Content

Quick Technical Check

Course Content

- Data Modelling, Data Structures, Schemas, Basic Data Management, Normal Forms
- Basic SQL Syntax
- Essential SQL Syntax
- Advanced Techniques
- Importing and Exporting Data to and from SQL
- SQL's relationship to the Machine Learning Pipeline

Course Tools

- DB Browser for SQLite: *Where we will write code*
- GitHub: *Module Overview*
- Etherpad: *Where we will keep track of session progress*
  - **Visit and complete the sign in prompt at the start every session**
- SQLite documentation: *For SQL specific questions*
- DrawIO or Lucid: *For Assignments*
- Code Share: *To share code during our live coding sessions*
  - This is for convenience only during live coding sessions, use the repo after the session instead
- Mentimeter (links vary): *Small in-class quizzes, easiest to participate on your phone if available, ungraded*

Course Content

Github Repo

https://github.com/UofT-DSI/sql

- Schedule
- These slides (HTML & PDF)
- Our database for live coding
- All in-class code
- Assignment details and rubrics
- Policies, due dates, etc

It is crucial you visit the repo throughout the course, as I may make minor changes and push new content.

Course Content

- This course is an *Introduction* to SQL
- At the end of the course, I hope you will:
  - Feel comfortable with SQL
  - Know how to search for the right thing on Stack Overflow
  - Read documentation
- We won't cover advanced topics like:
  - Stored Procedures, Triggers, Jobs
  - DBA work (monitoring, server setup, etc)
  - Complex ETL or tooling

Course Content

Assignments

- Two assignments, released on Monday of each week.
- Broken into three sections:
  - Section 1 focuses on database design
  - Sections 2 and 3 on SQL writing
- Each sections states about when you can start working on the answers
- Review questions/answers in Office Hours course support
- Database design sections are more time consuming
  - Especially Assignment 2. Do not put this off too much.
- SQL sections are designed to be relatively easy (with a couple of hard questions)
  - Reaffirms what we wrote together
  - Doing work on your own helps reinforce the learning
- ChatGPT probably won't help you much

Course Content

Grading

- Pass/Fail. Do the work, pass the course :)
- Assignment 1: 30% of mark
- Assignment 2: 70% of mark
- Review rubrics for full details
- Class Attendance: *not graded, come anyways!*
    - Let myself or course support know if you are unable to attend a lesson
    - Code along!! Best way to learn.

What questions do you have about the course?

Welcome

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Quick Technical Check

Quick Technical Check

Make sure to install DB Browser for SQLite by our next session.

If you haven't already, please download it here: https://sqlitebrowser.org/dl//.

For live coding:

- Please download/fork the FarmersMarket.db from our GH repo:
  - https://github.com/UofT-DSI/sql/blob/main/05_src/sql/farmersmarket.db
- Open it in SQLite with the "Open Database" button and navigate to wherever you have saved it

*Install Issues?**

If yes, please message your course support

Getting Started:

Welcome

What is SQL?

Data Modelling

What is SQL?

SQL

Flavours

Environments for SQL

What is SQL?

SQL

Flavours

Environments for SQL

SQL

SQL Fundamentals

- SQL: Structured Query Language
  - Pronounced as either S.Q.L. (ess-cue-ell) or “sequel”

- SQL is a *query* language rather than a programming language
  - Querying is closer to telling a computer *what you want*, rather than *what it has to do*
  - SQL code is often less reproducible than other programming languages because it's domain specific
    - Some SQL code, especially more advanced procedural code, is reproducible within the same flavour
  - SQL's domain is databases and is based on set theory

- Designed to manage data within Relational Database Management Systems (RDBMs), e.g.
  - MSSQL
  - Oracle DB
  - MySQL/MariaDB
  - PostgreSQL

SQL

SQL Formatting

- Like other programming/query languages, SQL has reserved keywords/commands to perform instructional operations
  - Generally, these keywords are written in all caps: `SELECT`
  - Most modern interpreters no longer require this, but it is the expected standard

- All statements/queries should end with a semicolon
  - A few SQL constructs (like common table expressions, we'll get to these later) require them, otherwise they are optional
    - I'll almost certainly forget to use them
    - There's some debate over whether or not it's best practice

SQL

SQL Formatting

- In SQL, white space and/or line breaks do not matter
  - Readability is important
  - Try to keep SQL statements to a reasonable screen width
  - Use sensible line breaks
  - Offset subqueries with indents

- Code is commented in/out with `--` rather than `#`
- Code blocks can be commented out with `/* */`

```
/*

somecode spanning
multiple lines

*/
```

What is SQL?

SQL

Flavours

Environments for SQL

Flavours

- RDBMs differ from one to the next:
  - different keywords
    - e.g. return only 10 rows: `SELECT TOP 10...` vs `SELECT ... LIMIT 10`
  - different syntax
    - e.g. not equal: `!=` or `<>` (or both)
  - other, more nuanced/complex differences
    - e.g. architecture, data types, etc

- We are using SQLite:
  - Super easy to get setup
  - Requires almost no overhead
  - Open source, *free*
  - Similar enough in syntax to learn on
  - Used all over the world and in many applications
    - e.g. Firefox uses a SQLite backend to write a user's history locally

Flavours

- Broad observations about Open Source systems:
  - Excellent at what they are designed for
  - Varying data types (SQLite has some unique ones!)
  - Not every command exists, but workarounds are usually possible
  - Some utilize RDBMs that feel extremely outdated

- Broad observations about enterprise systems:
  - Powerful and designed to handle edge cases
  - Feel a bit more refined
    - Can be version dependent
  - Tend to "lock in" businesses/organizations
    - Migration is costly, sometimes outrageously so
  - Newer players (Snowflake, Databricks, etc) and cloud providers (Azure, AWS, GCP, etc) offer a lot more functionality than just database querying
    - Sometimes use different terminology to describe SQL tasks

What is SQL?

SQL

Flavours

Environments for SQL

Environments for SQL

Databases

- Relational databases are a collection of tables, views, procedural code, and other SQL-assisting artefacts
  - Generally the data stored in a database will be related to a real-world concept
  - Backends to data-collecting systems are often databases
    - e.g. CRMs, EMR software, ERPs, web-based applications
  - Usually not connected to other databases unless deemed necessary
  - Often transactional, meaning data is actively being written to by frontend systems
  - Tables are normalized

- There are also non-relational databases, often referred to as NoSQL
  - We won't cover these
  - Common tools include: Amazon DynamoDB, Azure CosmosDB, MongoDB, Google Cloud Datastore

Environments for SQL

Data Warehouses and Data Marts

- Data Warehouses are highly structured collections of (usually tabular) data
  - Data has been processed for a specific purpose, e.g. analytics
  - Data has been centralized
    - Often with the assistance of ETL (Extract, Transform, Load) tools
  - Have a lot of overhead, require governance, and strict rigidity
  - Tables are denormalized
  - Very common for enterprises, but losing traction in many industries

- Data Marts are created from Data Warehouses to focus on a single subject
  - Designed to make Data Warehouses easier to use
  - Data is structured, but flexibility is driven by the purpose of the Data Mart
  - Some denormalized tables may be normalized or undergo even greater normalization
    - *The subject/purpose of the Data Mart might drive these types of decisions*
  - Common for enterprises that have Data Warehouses

Environments for SQL

Data Lakes and Data Swamps

- Data Lakes allow on-demand access to raw, semi-structured, structured, and unstructured data
  - Not defined by a specific purpose
  - Highly scalable
  - Can be transactional, if systems are designed to produce outputs into Data Lakes
  - Often data sources for machine learning pipelines live in Data Lakes
  - Inexpensive compared to Data Warehouses
  - Increasingly common for enterprises to shift towards Data Lakes, especially with support from newer tools like Snowflake, Databricks, etc, which can maximize the analytical value of a Data Lake

- Data Swamps...are poorly governed Data Lakes
  - Lack of documentation, lack of governance, poorly designed Data Lakes become Swamps
  - Avoid building these

What questions do you have?

Getting Started:

Welcome

What is SQL?

Data Modelling

Data Modelling

Relational Database Management Systems

Data Models

Structure of Data

Constraints

(…)

Data Modelling (continued)

Entity Relationship Diagrams

Attributes of an ERD: Entities & Relationships

Relationship Examples

Conceptual, Logical, Physical Models

Assignment 1 and 2 Data Modelling

Data Modelling

Relational Database Management Systems

Data Models

Structure of Data

Constraints

(…)

Data Modelling

Relational Database Management Systems

- Relational Database Management Systems (RDBMs) are software designed to:
  - Store large amounts of data
  - Utilize a query language to allow easy retrieval of the data
  - Allow multiple users to access the data simultaneously
  - Manage permissions for data access
  - Mitigate data corruption and unauthorized access

- Generally, data is stored in a *database*
  - A database is a collection of information
  - Within a database, a collection of objects (e.g. tabular data "tables") is stored

- RDBMs allow users to define interactions between these objects, such as:
  - Establish the relationship between objects
  - Define procedural scripts to query specific data or trigger an action
  - Schedule routine work (e.g. procedures to run, maintenance, etc)

Data Modelling

Relational Database Management Systems

Data Models

Structure of Data

Constraints

(…)

Data Modelling

Data Models

- A data model is a notation for describing data or information
- Data models consist of:
    - Structure of the data
    - Operations
    - Constraints on the data
    - Relationships

Data Modelling

Relational Database Management Systems

Data Models

Structure of Data

Constraints

(…)

Data Modelling

Structure of Data

- SQL is comprised of tables

Breed	Affectionate w/ Family	Good w/ Other Dogs	Shedding	Coat Type	Coat Length	Playfulness	Energy
Pugs	5	4	4	Smooth	Short	5	3
Akitas	3	1	3	Double	Medium	3	4
Samoyeds	5	3	3	Double	Long	5	4

- Tables have Attributes and Observations
  - In SQL we call Attributes "Columns"
    - e.g. Breed, Coat Type, Coat Length
  - and Observations "Rows"
    - e.g. Samoyed, Double, Long

- SQL databases require tables to be named
  - e.g. We can call this table "breed_traits"

Data Modelling

Structure of Data

- Columns are defined (and restricted, i.e. constrained) by data types
- Common ones include:
  - `INT` (integers: 1,2,3,-1,-2,-3)
    - most systems conserve storage space specifying their range
  - `FLOAT`, `DECIMAL`, `REAL` (decimal: 5.5, 3.333333)
  - `VARCHAR`, `NVARCHAR`, `TEXT` (text strings, with a maximum length associated: 'abc')
  - `DATE`, `DATETIME`, `TIME` (dates and times: '2023-01-09', '11:11:11.000')
- These may vary slightly by flavour (in SQLite they are simpler and less restricted)

- Data types are important:
  - They affect operation speed, storage size, data validity
    - Speed: it's computationally less expensive to compute smaller values
    - Storage: small is usually better, but the wrong size will affect systems; e.g. Psy's Gangnam Style exceeded 2,147,483,647 (32-bit signed, 2^32/2-1) views, causing YouTube to expand the view counter to 9,223,372,036,854,775,807 (64-bit signed, 2^64/2-1)
    - Validity: ensures columns contain the right type of data for operations, e.g. avoiding 5 + 'ten' = ??

Quick Mentimeter

Data Modelling

Relational Database Management Systems

Data Models

Structure of Data

Constraints

(…)

Data Modelling

Constraints

- Data Models also specify constraints
- Constraints are rules that must be followed:
  - Referential-Integrity constraints
    - Ensure that values in one table have corresponding values in another table
  - Attribute Constraints
    - Ensure that certain types of values are always consistent within columns
    - May also ensure whether values are unique, not missing, etc

Data Modelling

Constraints

- NULL and NOT NULL
  - If a value can be missing or not
- UNIQUE
  - All values are different
- PRIMARY KEY (PK)
  - Ensures each value in a column is unique within the table (e.g. an ID field)
  - One PK per table
  - Cannot be NULL
  - Ensures database integrity by restricting record deletion
- FOREIGN KEY (FK)
  - Creates a linkage between a column in one table and a column in another table
    - Generally, foreign keys are linked to primary keys
    - Sometimes share the same name as the linked column, but this isn't required
    - Linkage requires data types to be the same
  - As many FKs as needed per table
  - May be NULL
  - Record can be deleted

Data Modelling

Constraints

Why do we need Primary and Foreign Keys?

- Formalizing the relationship between PKs and FKs ensures:
  - New records added to tables require a matching value when a relationship exists
    - *orders* are made by *customers*
    - *orders* refer to *products* that exist
  - Deleted records don't make data elsewhere meaningless
    - *customers* who have had *orders* can't be deleted without deleting the orders first
    - *products* associated with *orders* can't be deleted without deleting the orders first
- The PK-FK relationship can sometimes feel a bit backwards: by establishing an FK we are determining what is allowed to happen!

customer_id (PK)	address	name
10	42 Wallaby Way	TR
11	221B Baker St	NN
12	124 Conch St	JZ
13	4 Privet Dr	LM

order_id (PK)	customer_id (FK)	product_id (FK)
93	11	123
94	11	789
95	13	456
96	10	101

product_id (PK)	name	price
123	Pen	2
456	Wand	17
789	Notepad	6
101	Lamp	15

Data Modelling

Constraints

Why then do we *require* PKs to be unique

- The PK is an identifier for each row
  - Much like how we all have various "ID" numbers to identify us to schools/organizations/governments/etc
  - Some identifying data isn't inherently unique (e.g. name, date of birth) because others can share the same values
- Ensures we are identifying the correct corresponding row of the relationship
  - *This* order was made by *this* customer for *this* product
    - The customer_id in the customer table is unique so that we know exactly which customer made the purchase
    - The product_id in the product table is unique so that we know exactly what was purchased

customer_id (PK)	address	name
11	221B Baker St	NN

order_id (PK)	customer_id (FK)	product_id (FK)
93	11	123
94	11	789

product_id (PK)	name	price
123	Pen	2
789	Notepad	6

- The customer_id in the order table does not need to be unique: Why?
  - Because a customer can make more than one order

Data Modelling

Constraints

What about *composite* keys?

- Sometimes no single column in a table is unique
  - In this case, in order to make a PK unique, we build "composite" keys
- Composite keys use a combination of columns to uniquely identify each row
- This can be useful to enforce relationships between two or more attributes
- Quite a few of Farmers Market PKs are composite keys
  - customer_purchases for example uses a composite key on product_id, vendor_id, market_date

Data Modelling (continued)

Entity Relationship Diagrams

Attributes of an ERD: Entities & Relationships

Relationship Examples

Conceptual, Logical, Physical Models

Assignment 1 and 2 Data Modelling

Data Modelling

Entity Relationship Diagrams

- Entity Relationship Diagrams (ERDs) are diagrams depicting the structure of tables within a database
  - This both *identifies the tables* and *describes their relationships*

- ERDs are useful for:
  - Database design
  - Debugging
  - Writing logical, consistent, and efficient queries

- There are three levels of detail for ERD depictions:
  - Conceptual model
  - Logical model
  - Physical model

Data Modelling (continued)

Entity Relationship Diagrams

Attributes of an ERD: Entities & Relationships

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Assignment 1 and 2 Data Modelling

Data Modelling

Attributes of an ERD Entity

- For a given table:
  - Name
  - Relationship to another table
  - Column Names
  - Column Types
  - Primary Keys (if present)
  - Foreign Keys (if present)

Attributes of an ERD Relationship

- Defines which columns are related
- Defines what type of relationship exists:
  - One-to-One
  - One-to-Many
  - Many-to-Many

Data Modelling (continued)

Entity Relationship Diagrams (ERDs)

Attributes of an ERD: Entities & Relationships

Relationship Examples

Conceptual, Logical, Physical Models

Assignment 1 and 2 Data Modelling

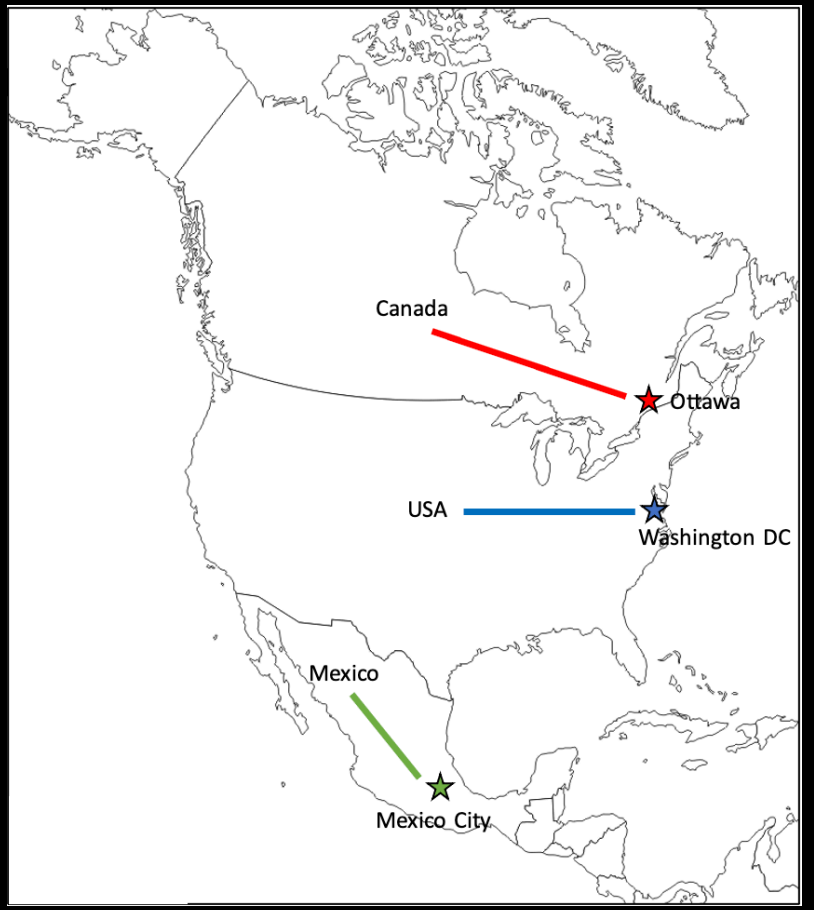
Data Modelling

Relationship Examples

One-to-One: where a given row within a table is associated with only a single row in another table

Table 1: Country — Table 2: Capital City

Table 1:Country		Table 2:Capital
Canada	1:1	Ottawa
USA	1:1	Washington DC
Mexico	1:1	Mexico City



Data Modelling

Relationship Examples

One-to-Many: where a given row within a table can be referenced by multiple rows in another table

Table 1: Country — Table 2: States

Table 1:Country		Table 2:States
Canada	1:∞	Alberta
Canada	1:∞	British Columbia
Canada	1:∞	...(11 more rows)
USA	1:∞	Alabama
USA	1:∞	Alaska
USA	1:∞	...(48 more rows)
Mexico	1:∞	Aguascalientes
Mexico	1:∞	Baja California
Mexico	1:∞	...(30 more rows)

Data Modelling

Relationship Examples

Many-to-Many: where multiple rows within a table can be referenced by multiple rows in another table

Table 1: Country — Table 2: Membership

For this example, consider different ways to define "European" membership, such as whether or not a country: 1) is a member of the EU, 2) uses the Euro, or 3) has abolished border controls (Schengen Agreement)

Country	Country ID
Slovenia	001
Sweden	002
Switzerland	003
...(more countries)	...

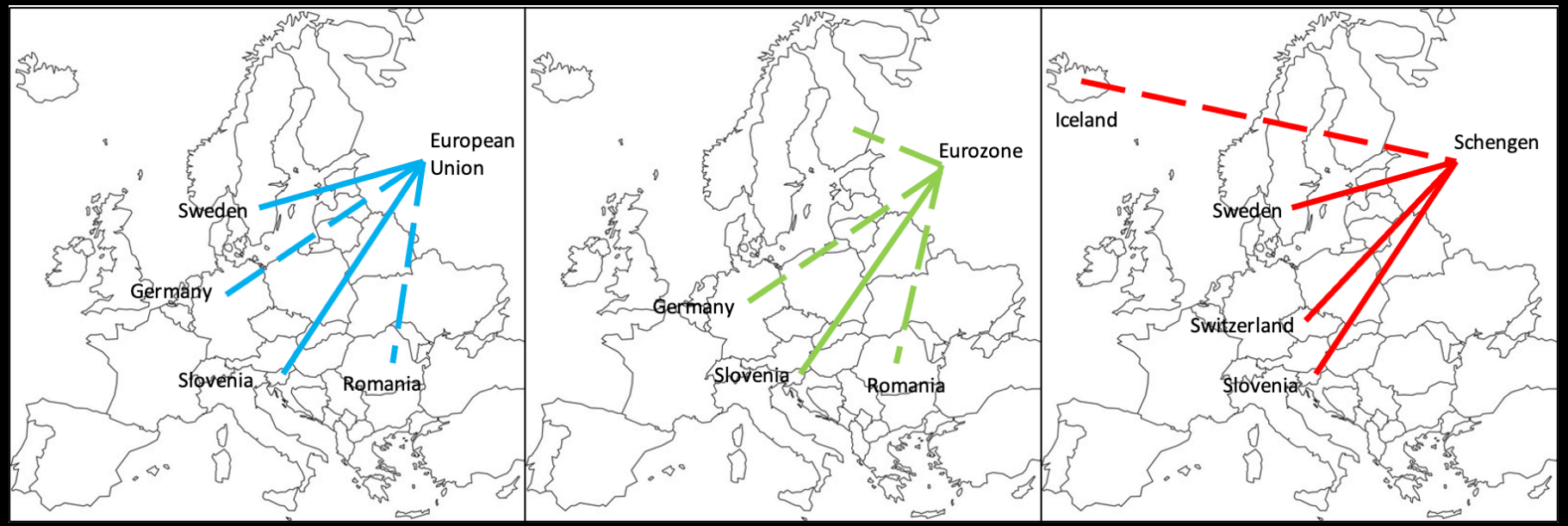
Membership	Member ID
EU	10
Eurozone	11
Schengen	12

Country ID		Member ID
001	∞:∞	10
001	∞:∞	11
001	∞:∞	12
002	∞:∞	10
002	∞:∞	12
003	∞:∞	12

Data Modelling

Relationship Examples

Many-to-Many: where multiple rows within a table can be referenced by multiple rows in another table



We can create even more Many-to-Many relationships if we created a table including NATO/UN membership, because many non-European countries are NATO/UN members.

Quick Mentimeter

Data Modelling (continued)

Entity Relationship Diagrams

Attributes of an ERD: Entities & Relationships

Relationship Examples

Conceptual, Logical, Physical Models

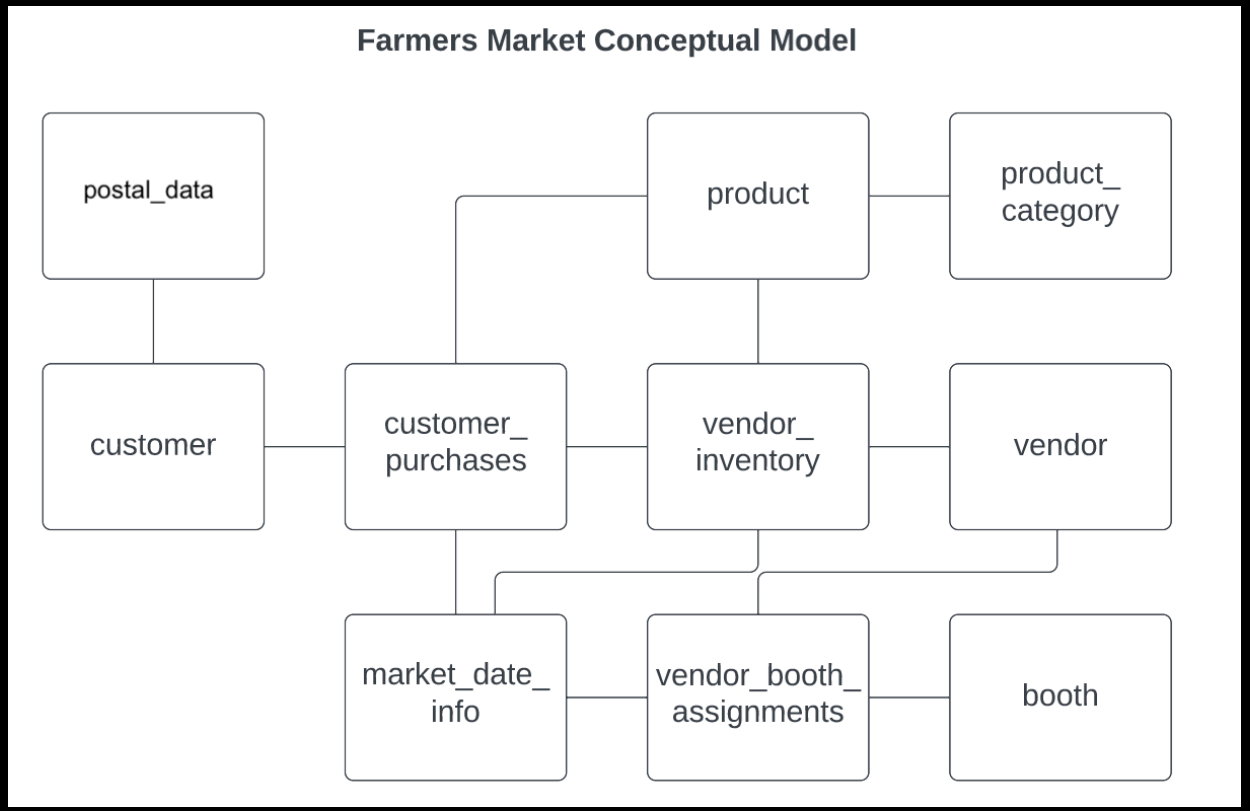
Assignment 1 and 2 Data Modelling

Data Modelling

Conceptual Models

- Define the tables (objects/entities) and their relationships

- Our Farmers Market database:
  - 10 tables
  - Relationships between these tables
    - e.g. product and product_category: *what type of thing a product is*
    - product and customer_purchases: *what products a customer has bought*
    - product and vendor_inventory: *what products each vendor has available*
  - Not all tables share a relationship to one another, but all tables have at least one relationship

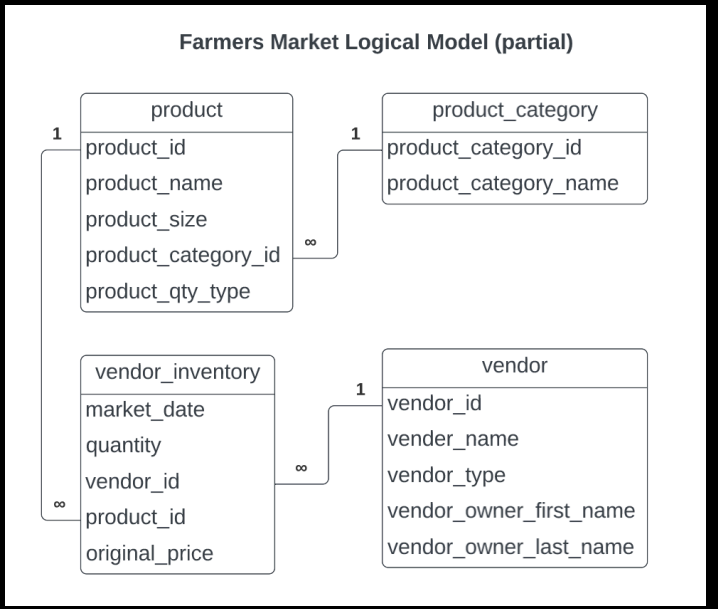


Data Modelling

Logical Models

- Add additional detail to the conceptual model by adding column names for each table
- Often indicate the type of relationship
  - One-to-One
  - One-to-Many
  - Many-to-Many

- Our (partial) Farmers Market database:
  - product (5 columns) shares a One-to-Many relationship with vendor_inventory (5 columns) on product_id
  - product_category (2 columns) shares a One-to-Many relationship with product (5 columns) on product_category_id
  - _____ shares a _____ relationship with _____ on vendor_id

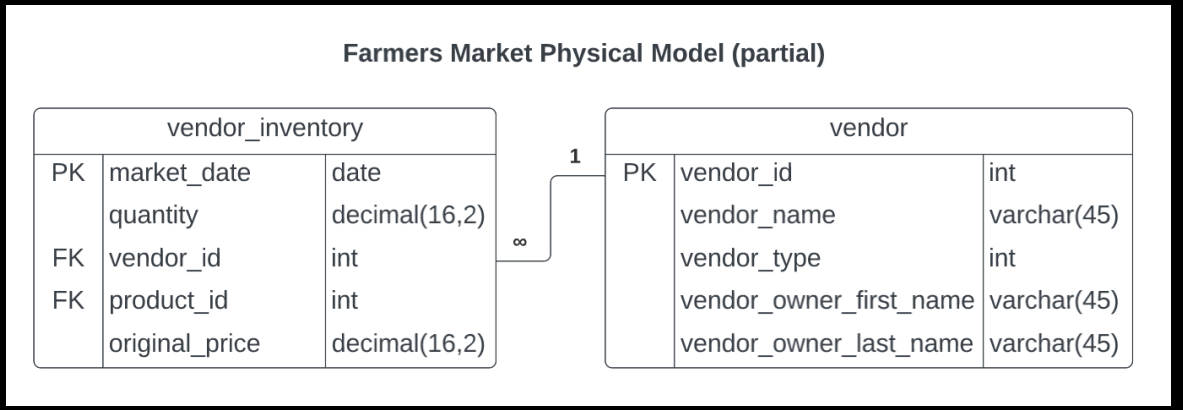


Data Modelling

Physical Models

- Add additional detail to the logical model by adding key type and column data type

- Our (partial) Farmers Market database:
  - vendor_id (int) is the PK for vendor, which shares a One-to-Many relationship with vendor_inventory on vendor_id (FK)
  - product_id (int) is an FK for vendor_inventory (*so elsewhere in this diagram, we'd connect this to a PK of another table*)
  - market_date (date) is the PK for vendor_inventory
    - why? 💭💬 Think, Pair, Share



What questions do you have about Data Modelling?

Data Modelling (continued)

Entity Relationship Diagrams

Attributes of an ERD: Entities & Relationships

Relationship Examples

Conceptual, Logical, Physical Models

Assignment 1 and 2 Data Modelling

Data Modelling

Assignment 1, Section 1: Meet the farmersmarket.db

Prompt 1) Choose two tables and create a logical data model. There are lots of tools you can do this (including drawing this by hand), but I'd recommend Draw.io or LucidChart.

A logical data model must contain:

- table name
- column names
- relationship type

Please do not pick the exact same tables that I have already diagrammed. For example, you shouldn't diagram the relationship between `product` and `product_category`, but you could diagram `product` and `customer_purchases`.

HINTS:

- You will need to use the Browse Data tab in the main window to figure out the relationship types.
- You can't diagram tables that don't share a common column (see conceptual model)
- The column names can be found in a few spots (DB Schema window in the bottom right, the Database Structure tab in the main window by expanding each table entry, at the top of the Browse Data tab in the main window)

Data Modelling

Assignment 2, Section 1: Design a Logical Model

Prompt 1) Create a logical model for a small bookstore. 📚

At the minimum it should have employee, order, sales, customer, and book entities (tables). Determine sensible column and table design based on what you know about these concepts. Keep it simple, but work out sensible relationships to keep tables reasonably sized.

Additionally, include a date table.

There are several tools online you can use, I'd recommend Draw.io or LucidChart.

HINT: You do not need to create any data for this prompt. This is a conceptual model only.

Prompt 2) We want to create employee shifts, splitting up the day into morning and evening. Add this to the ERD.

Prompt 3) The store wants to keep customer addresses. Propose two architectures for the CUSTOMER_ADDRESS table, one that will retain changes, and another that will overwrite. Which is type 1, which is type 2?

HINT: search type 1 vs type 2 slowly changing dimensions.

What questions do you have about anything from today?