DATA + INFORMATION ARCHITECTURE

THIS SESSION'S LEARNING OBJECTIVES

Primary objective: Increase your awareness of what you need to consider on the data front in order to run, manage, create and instigate successful data-driven projects.

Supporting objectives:

- be exposed to many of the concepts and terms at play in today's data world – e.g. data model, many-to-many relationship, database, noSQL, query, data management.
- experience creating a conceptual model and then turning this into a particular type of data model, based on a use-case.

SOMETHING OLD, SOMETHING NEW?

Since you all have been chosen for the data stream, perhaps you are all already 'data people'.

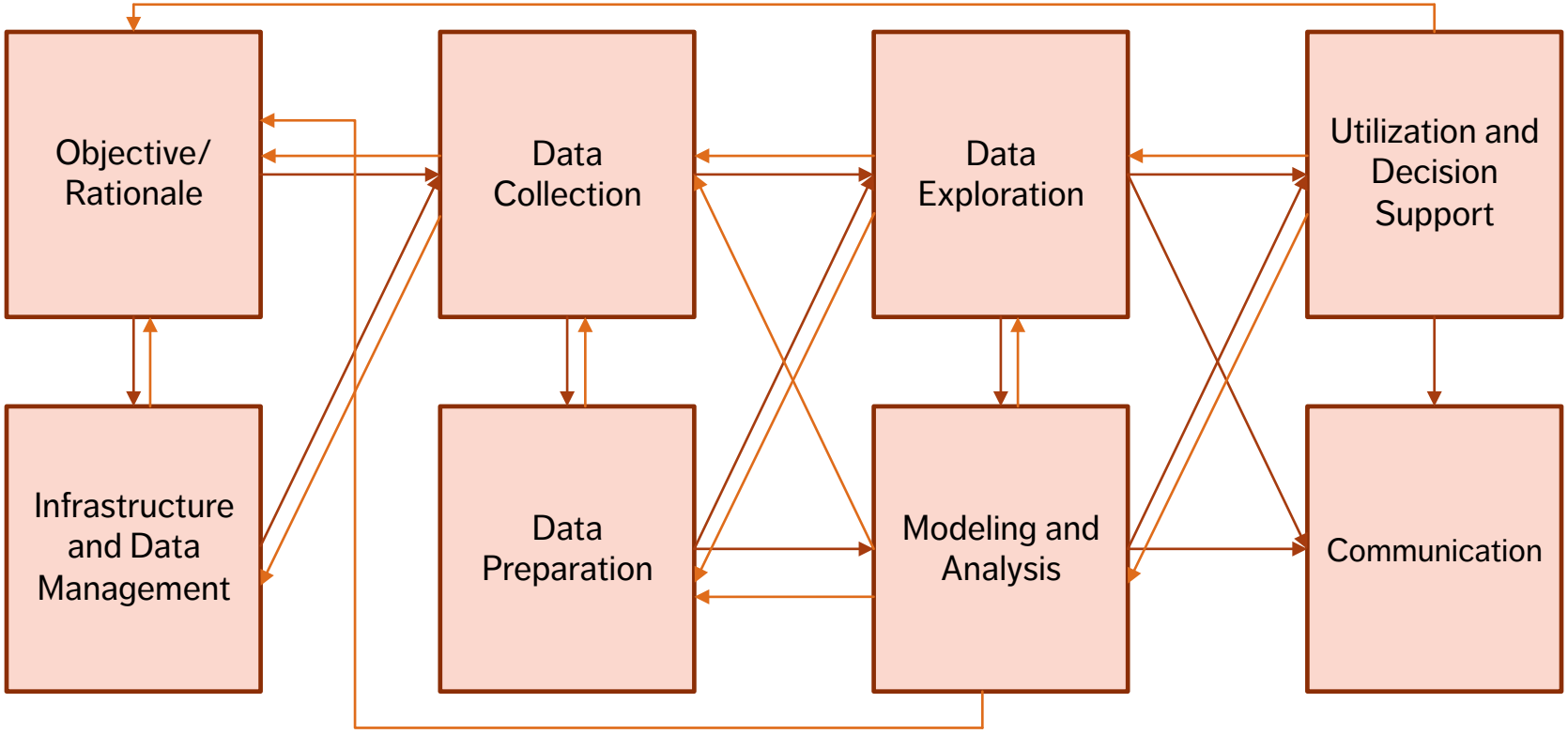
Many of these concepts and skills will be somewhat familiar to you already.

However – data and knowledge architecture concepts are critical in designing a data-driven project, so we can't just assume you are!

Hopefully some new concepts for everyone, still! Ontologies, any one?

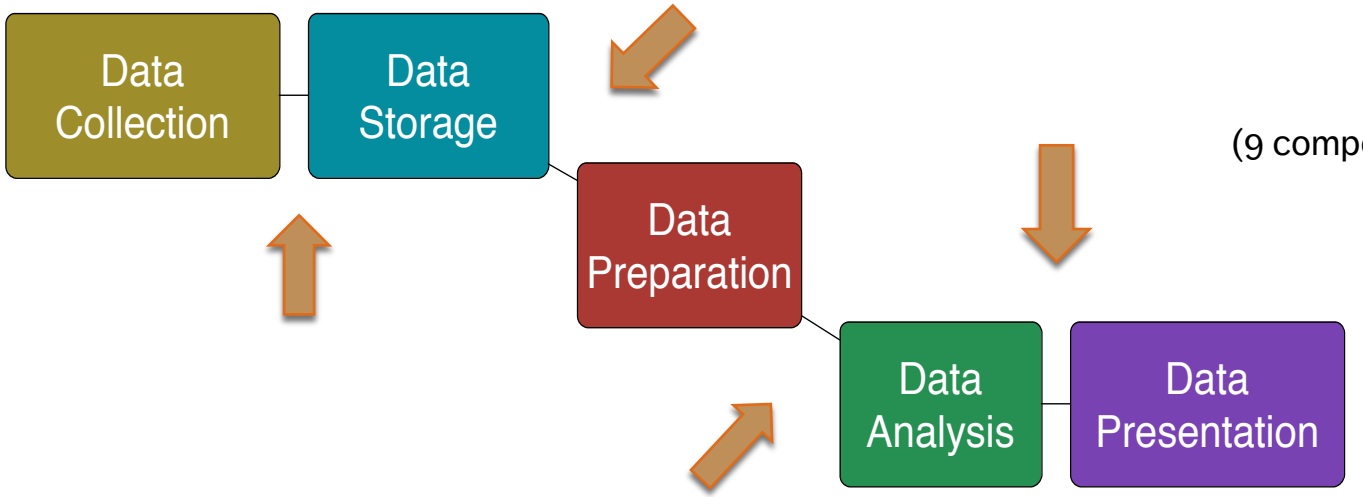
SOME CONTEXT

THE (MESSY) ANALYSIS PROCESS



AN IMPLEMENTED (AUTOMATED) DATA PIPELINE

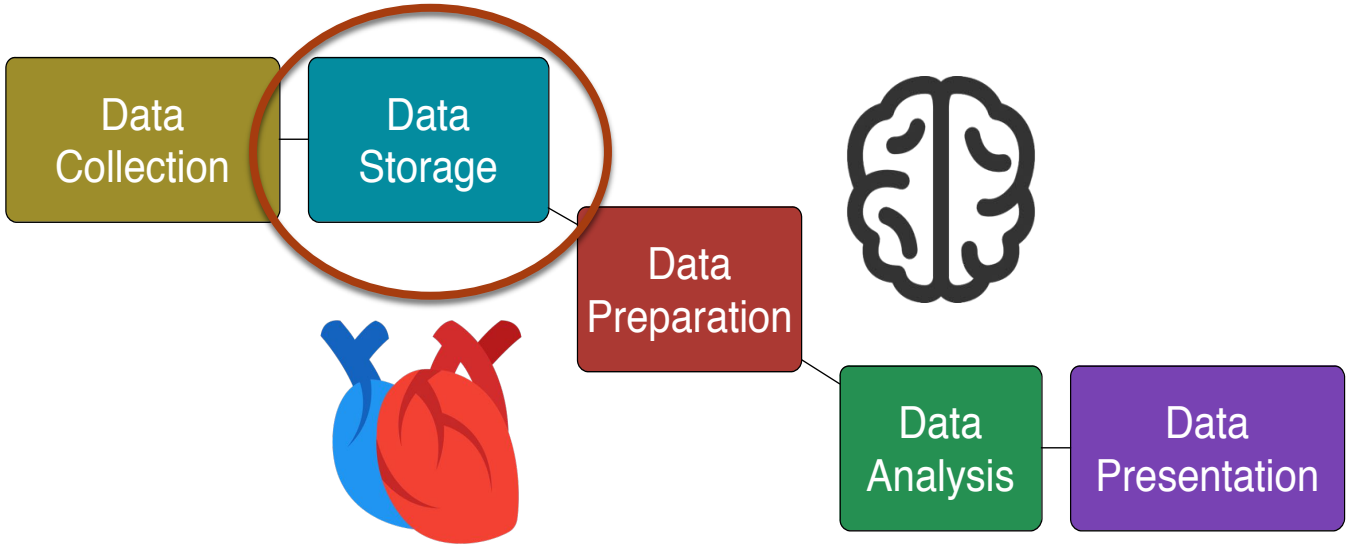
In the **service delivery context**, you may eventually want one of these...



(9 component parts)

(as always - beware model 'drift'!)

AN IMPLEMENTED (AUTOMATED) DATA PIPELINE



DATA SOURCES

GROUP DISCUSSION: A FEW FUNDAMENTAL DATA QUESTIONS

- **Why** do we collect data? What can we **do** with data?
- Where does data come from?
- Assuming we collect data so we can have a *collection* of data – what does 'a collection' of data look like? How would you describe one?
- Do we need to distinguish between data, information, knowledge?

WHAT IS THIS?

MOTIVATIONS FOR COLLECTION

Three functions, historically:

- Record Keeping (People/Societal Management!)
- Science - New General Knowledge
- Intelligence - Business, Military, Police, Social? Domestic? Personal!

MOTIVATIONS FOR COLLECTION

Each of these three functions have traditionally used different **sources** of information.

They have collected **different types of data.**

They also have had **different data cultures** and terminologies!

In data science (interdisciplinary!) we may run into all of them on the same project.

DIFFERENT DATA CULTURES, DIFFERENT TERMS

Business Intelligence:

- data warehouse + data mart
- data 'dimension' (= data set)
- hierarchical data (slices)
- data element
- dimension table + fact table

Science/Statistics:

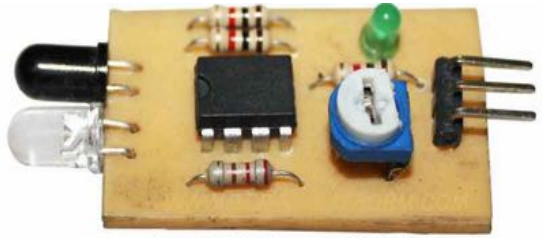
- experimental data
- trials
- participants
- variables
- correlation

Record Management:

- information architecture
- file plan
- Information resource
- field
- form
- subject

SOME SOURCES OF DATA

- records of activity
- (scientific) observations
- sensors + monitoring
- computers!



IR SENSOR (TRANSCEIVER)

ENTER COMPUTERS! AND COMPUTER SCIENCE!

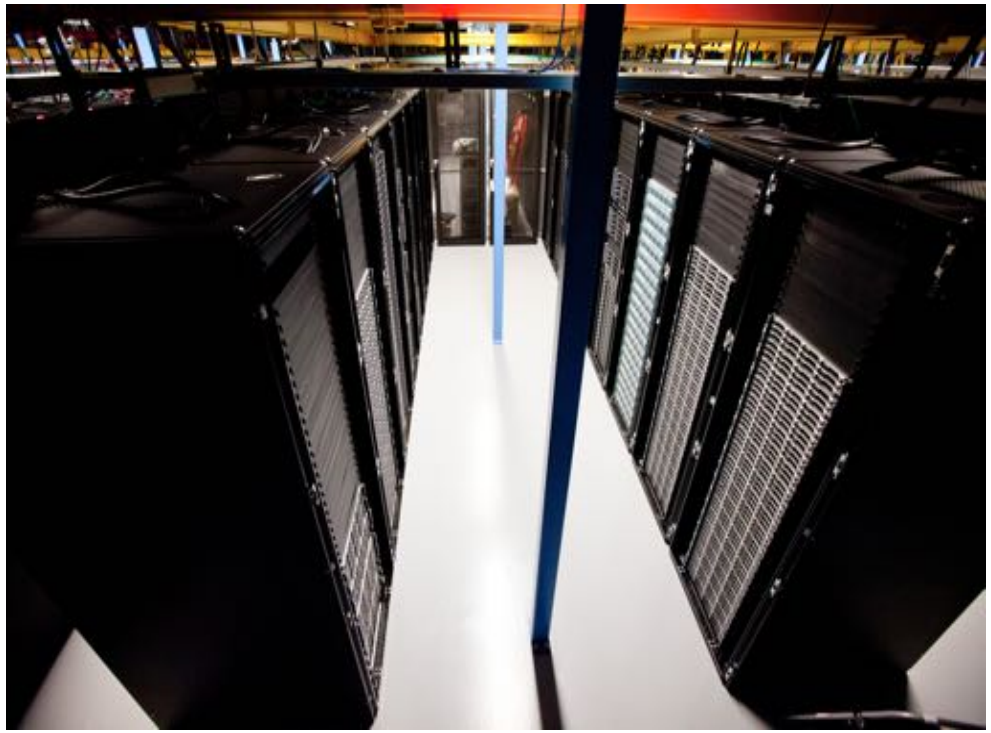
Computer science (and information science) has its own theoretical, **fundamental** viewpoint about data, and information.

Computers operate over data in a fundamental sense - 1s and 0s that represent numbers, letters, etc. – **data becomes digital**.

Pragmatically, data is now stored on computers, and is accessible through our world-wide computer network.

DATA IS REAL!

- Data is a representation, but data is still physical!
- Data has physical properties - it takes up physical space! It requires energy to work with it.



DATA DECAYS

Data ages over time - it has a shelf life.

We use the phrase "rotten data" "decaying data":

- **literally** - in the sense that the data storage medium might decay
- **metaphorically** - when the data no longer accurately **represents** the relevant objects and relationships or even when those objects no longer exist in the same way

Your data must be ‘fresh’, ‘current’, not ‘stale’ (context and model dependent!)

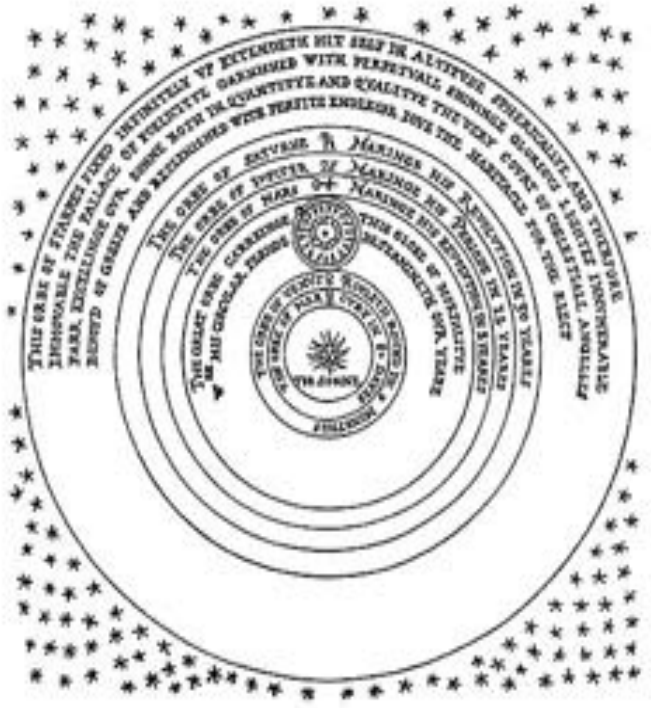
BEFORE THE DATA

CORE CONCEPTS

How do we cut across all of the different disciplines that use data?

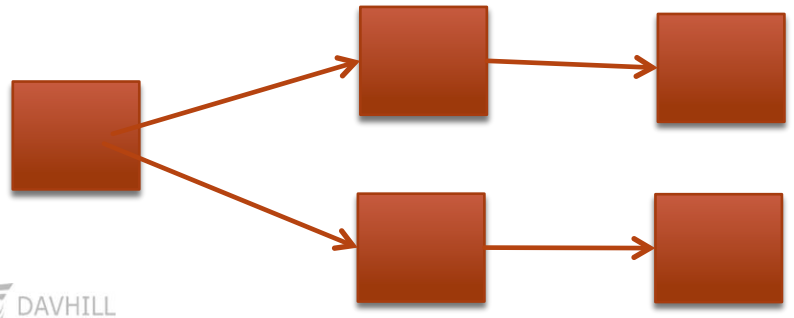
Core (systems) concepts or elements:

- object – attributes (concrete or abstract)
- multiple objects - **relationships** between these objects/attributes
- how these elements change over time



RELATIONSHIPS WITHIN SYSTEMS

- some fundamental relationships:
  - part-whole
  - is-a
  - is-a-type-of
  - cardinality (one-to-one, one-to-many, many-to-many)
- some more object specific relationships:
  - ownership,
  - social relationships
  - becomes,
  - leads-to



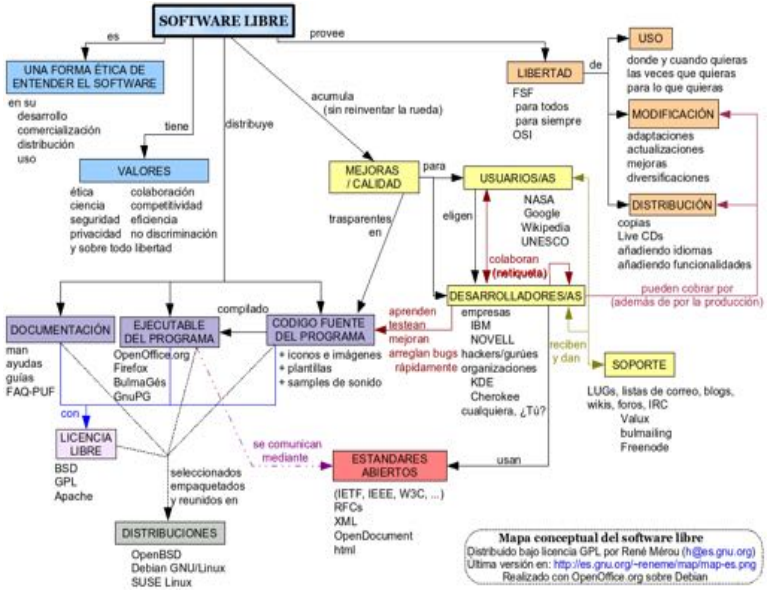
CONCEPTUAL MODEL OF A SYSTEM

A conceptual model is, roughly speaking:

- a model that is not implemented (e.g. as a scale-model or computer code), but one which exists only conceptually
- a diagram or verbal description of a system (e.g. boxes and arrows, mind maps, lists, definitions)

Focus is not necessarily on capturing specific behaviors but emphasizing **possible states**.

Focus is on object types, not on specific instances – goal is abstraction!



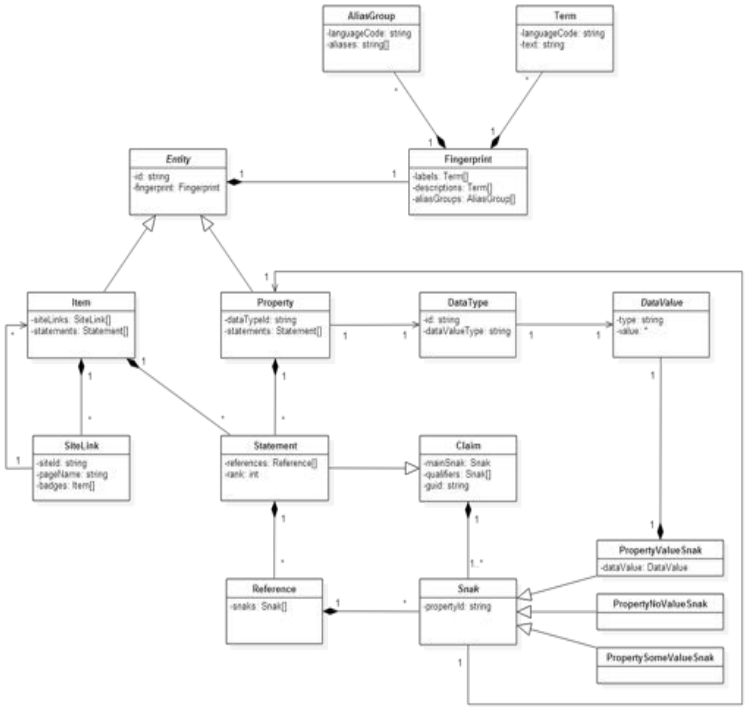
FORMAL CONCEPTUAL MODELLING LANGUAGES

Conceptual modelling is not an exact science – it's more about making your internal conceptual models **explicit** and **tangible**.

It provides you with an opportunity to examine and explore your ideas and assumptions.

That said, various efforts have been made to formalize conceptual modelling:

- UML – Universal Modelling Language
- Entity Relationship (ER) Models - but they are generally connected to relational databases



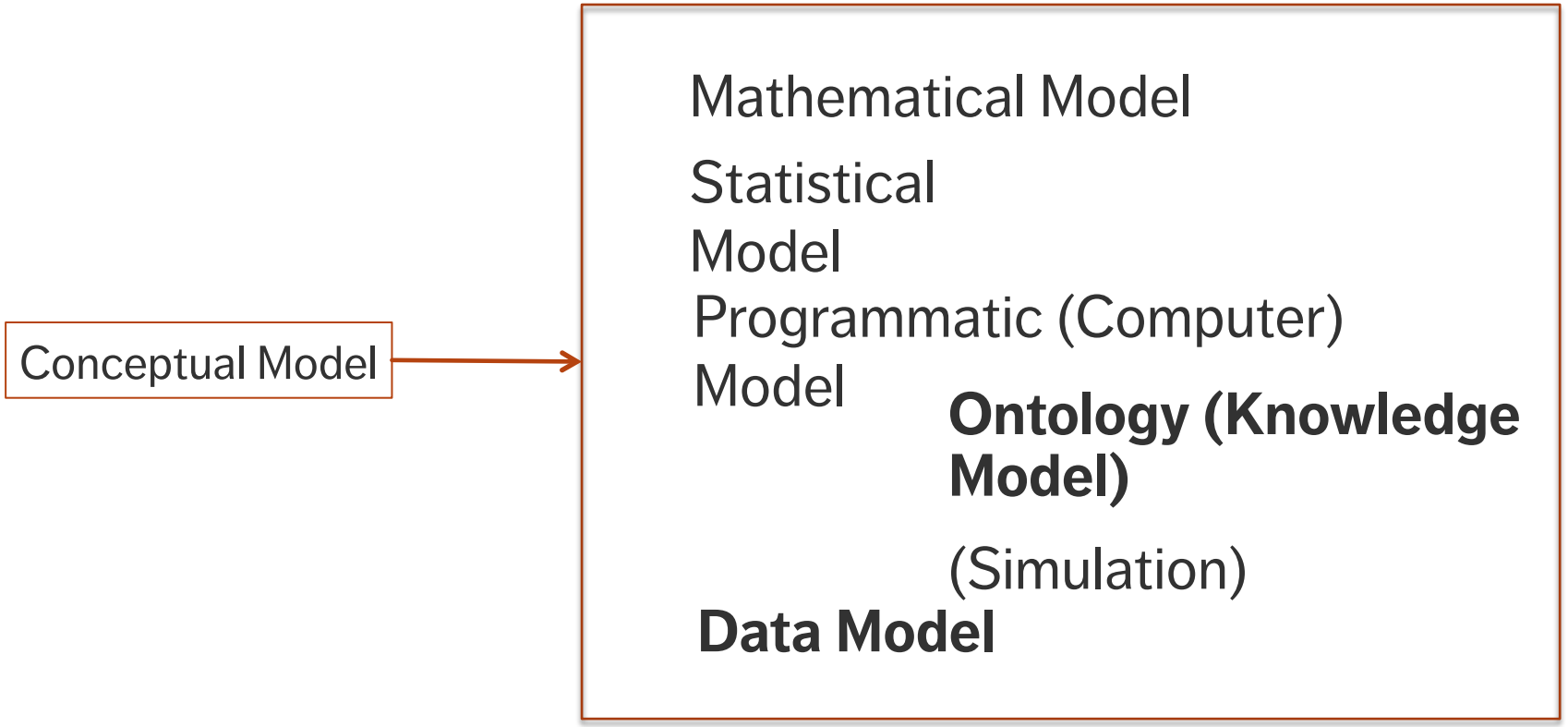
PUTTING THIS INTO PRACTICE

Pick a system of relevance to you, and generate a conceptual model that encompasses:

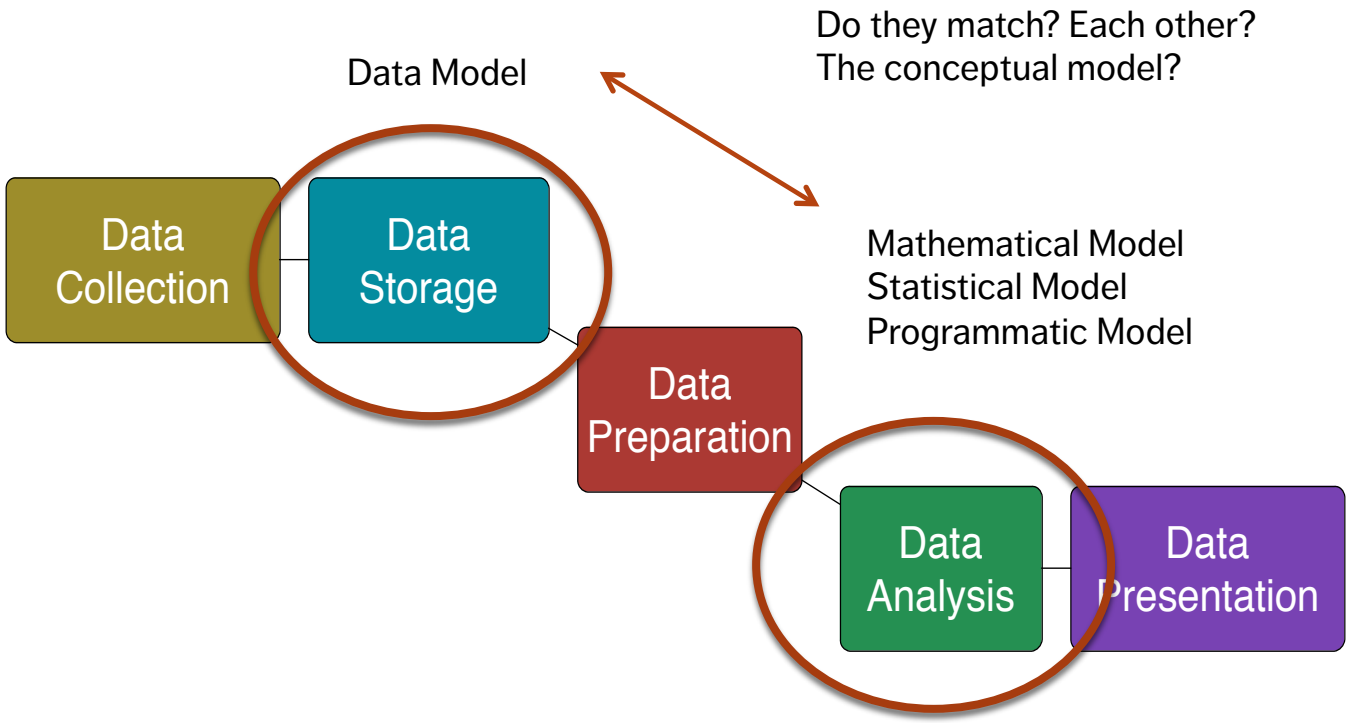
- objects - especially **key objects** (could be abstract or concrete)
- properties of these objects and values of these properties
- relationships between objects (part-whole, is-a, object-specific, one-to-many)
- relationships between properties across *instances* of an object type

DATA AND KNOWLEDGE MODELLING

METHODOLOGICAL MODELS



AN IMPLEMENTED (AUTOMATED) DATA PIPELINE



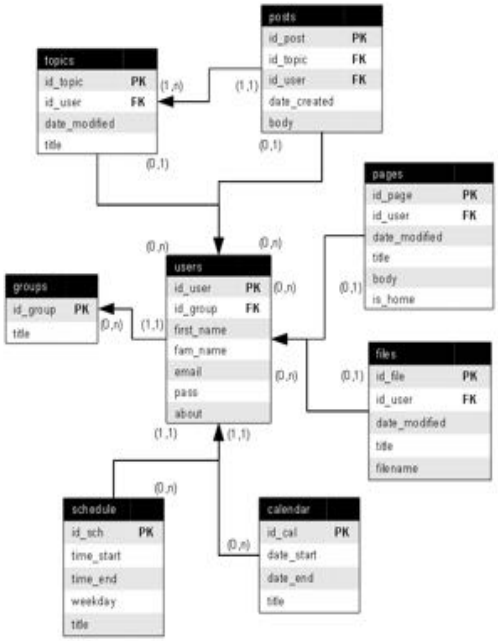
HOLD ON TO THOSE FUNDAMENTAL CONCEPTS

How to structure your **data** and **knowledge** so that it can be:

- usefully stored
- added to
- usefully and efficiently extracted from that store (extract – transform – load)
- operated over by **humans** and **computers** (programs, bots, A.I.)

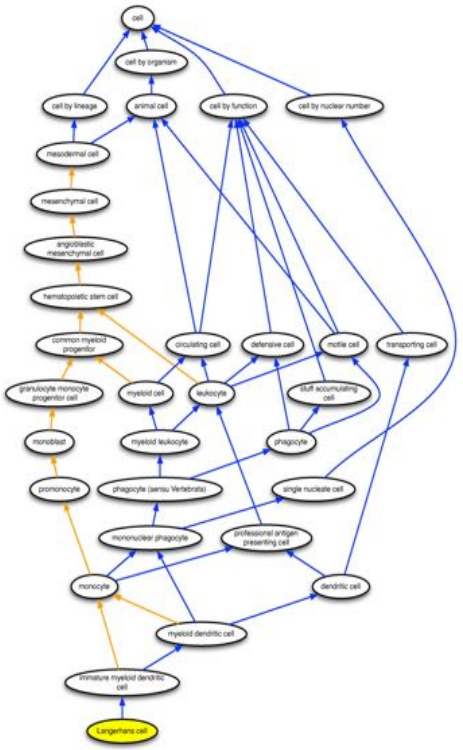
WHAT IS DATA MODELLING

- A data model is an abstract (logical) description of a system, constructed in terms that can then be implemented as the structure of a type of data management software.
- You might argue that it is half way between a conceptual model and a database implementation.
- The data itself is about **instances** – the model is about the **object types**.
- There is another option that is worth considering on this front – **ontologies**.



ONTOLOGY – KNOWLEDGE MODEL

- A structured, machine-readable collection of **facts** about a domain.
- Motivated by a desire to create increasingly machine readable but still conceptually sophisticated data.
- you could describe in a slightly tongue in cheek manner as 'a data model on steroids'.
- An attempt to get closer to the level of detail of a full conceptual model.



IDLEWYLD Sysabee DAVHILL

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METADATA TO PROVIDE CONTEXT

- We lose something when we move from our conceptual model to a specific type of model – e.g. the data or knowledge model.
- One way of keeping the context is to provide (hopefully rich) metadata – data **about** our data!
- Metadata is crucial when it comes to carrying out strategies for working across datasets.
- Ontologies can also play a role here!

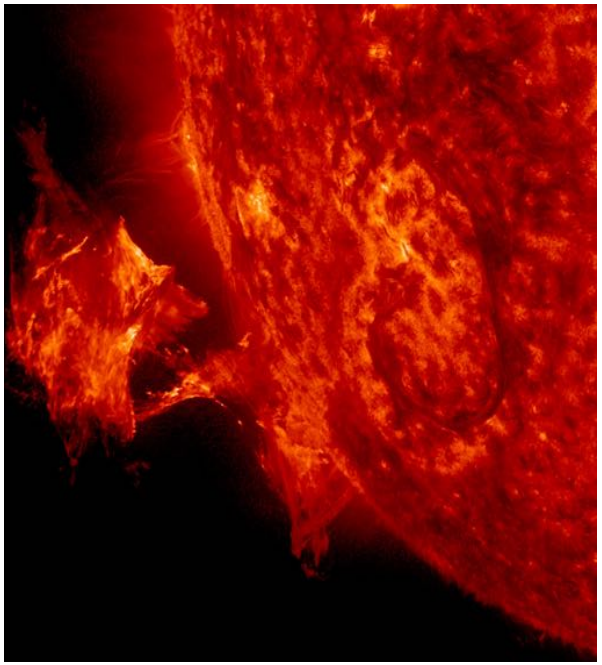
STRUCTURED VS UNSTRUCTURED DATA

A major motivator for some of the new developments in types of databases and other data storing strategies is the increasing availability of **unstructured** data and also '**blob**' data.

Structured Data: labelled, organized, discrete, structure is constrained and pre-defined

Unstructured Data: not organized, no specific pre-defined structure data model – e.g. text in a document

Blob Data: Binary Large Object (BLOb) – images, audio, multi-media



WHAT IS DATA MODELLING

We're going to look at four different options that are currently popular in terms of fundamental **data and knowledge** modelling or structuring strategies:

- key-value pairs (e.g. JSON)
- triples (e.g. resource description framework (RDF))
- graph databases
- relational databases

NoSQL

KEY - VALUE STORES AND TRIPLE STORES

These are relatively unstructured ways to store data:

- **Key Value**: all data is simply stored as a giant list of keys and values, where the key is a name or label (possibly of an object) and the value is a value associated with this.
- **Triple**: Data is stored as subject – predicate – object

EXAMPLES

apple type - apple colour

Granny Smith - green

Red Delicious – red

person - shoe size

Jen Schellinck - women's size 7

Colin Henein - men's size 10

word - definition

url – webpage

report name – report (document file)

Triples add a verb to the mix:

Person - is - age

Object - is-colour - colour

NAILING DOWN THE DETAILS

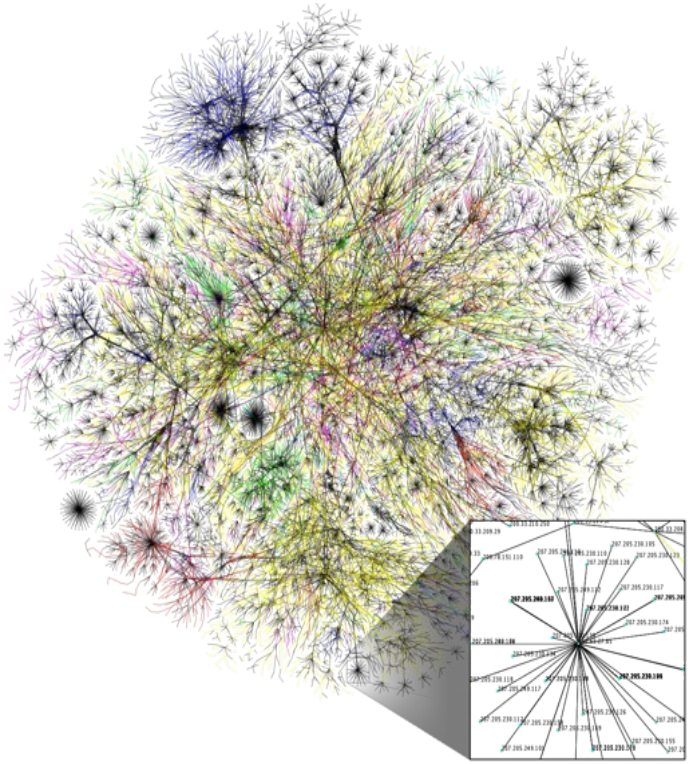
- Both strategies results in a large amount of flexibility when it comes to the 'design' of the data storage.
- In terms of the **implementation** of these data models the devil is in the details, and their extreme flexibility can add to this challenge.
- See for example: https://softwareengineering.stackexchange.com/questions/321534/what-json-structure-to-use-for-key-value-pairs

GRAPH DATABASES

Emphasis on the **relationships** between different types of objects, rather than between an object and the properties of that object.

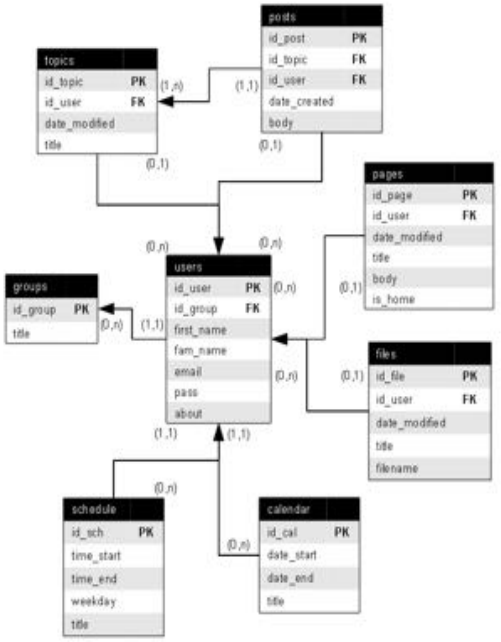
The data model:

- objects represented by nodes
- relationships between these objects represented by edges
- objects can have a relationship with other objects of that same type - person is-a-sibling-of person



RELATIONAL DATABASES

- Data stored in a series of tables
- Broadly speaking, each table represents an object and some properties related to this object.
- Special columns in tables connect object instances across table.



RELATIONAL DATABASES

- Example: I live in a house that has a particular address.
- Sometimes the property of the house will be stored in the table that stores information about me.
- In other cases it will make more sense to store information about the house in its own table.
- The form of relational databases are driven by whether or not relationships are one-to-one, one-to-many or many-to-many (cardinality)

PUTTING IT INTO PRACTICE

Come up with an example of a one to one, one to many and many to many relationship? How clear cut is the cardinality of this relationship?

What is the cardinality of the father to child relationship?

PROS, CONS AND USE CASES OF EACH

Relational Database: widely supported, well understood, works well for many types of systems and use cases. But difficult to change once implemented, doesn't deal with relationships well (despite the name).

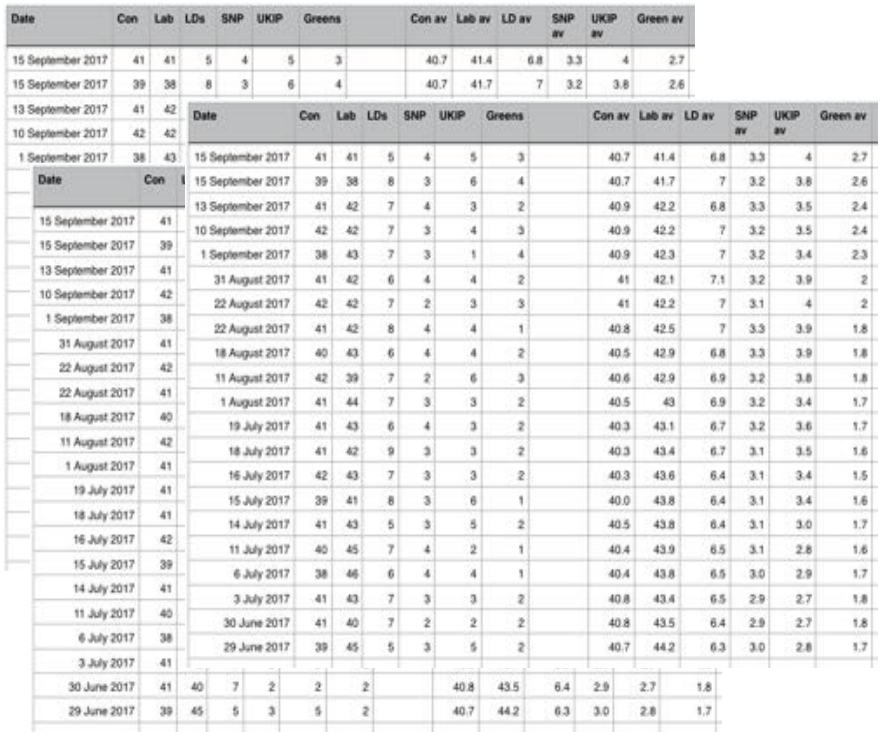
Key-Value Stores: can take any sort of data, don't need to know much about it's structure advance, if you have many missing values these won't take up space. But can be messy and mysterious, difficult to find data.

Graph Databases: fast and intuitive if you are using heavily relation-based data, might be the only option if your data is like this because traditional databases may slow to a crawl. But probably overkill/too specialized if your data is not like this, not yet widely supported.

A NOTE ON FLAT FILES AND SPREADSHEETS

What about keeping your data in a single giant table (spreadsheet)? Or multiple spreadsheets? How bad can it be?

Wayne Eckerson coined the term ‘spreadmart’ (as opposed to data mart) to describe a situation with many (ad hoc) spreadsheets as a data strategy.



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15 September 2017	41	41	5	4	5	3		40.7	41.4	6.8	3.3	4	2.7
15 September 2017	39	38	8	3	6	4		40.7	41.7	7	3.2	3.8	2.6
13 September 2017	41	42	7	4	3	2		40.9	42.2	6.8	3.3	3.5	2.4
10 September 2017	42	42	7	3	4	3		40.9	42.2	7	3.2	3.5	2.4
1 September 2017	38	43	7	3	1	4		40.9	42.3	7	3.2	3.4	2.3
31 August 2017	41	42	6	4	4	2		41	42.1	7.1	3.2	3.9	2
22 August 2017	42	42	7	2	3	3		41	42.2	7	3.1	4	2
22 August 2017	41	42	8	4	4	1		40.8	42.5	7	3.3	3.9	1.8
18 August 2017	40	43	6	4	4	2		40.5	42.9	6.8	3.3	3.9	1.8
11 August 2017	42	39	7	2	6	3		40.6	42.9	6.9	3.2	3.8	1.8
1 August 2017	41	44	7	3	3	2		40.5	43	6.9	3.2	3.4	1.7
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18 July 2017	41	42	9	3	3	2		40.3	43.4	6.7	3.1	3.5	1.6
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11 July 2017	40	45	7	4	2	1		40.4	43.9	6.5	3.1	2.8	1.6
6 July 2017	38	46	6	4	4	1		40.4	43.8	6.5	3.0	2.9	1.7
3 July 2017	41	43	7	3	3	2		40.8	43.4	6.5	2.9	2.7	1.8
30 June 2017	41	40	7	2	2	2		40.8	43.5	6.4	2.9	2.7	1.8
29 June 2017	39	45	5	3	5	2		40.7	44.2	6.3	3.0	2.8	1.7

A NOTE ON FLAT FILES AND SPREADSHEETS

- **Pros** - very efficient if you are only collecting data once, about one particular type of object (e.g. scientific studies!), some types of analysis require you to have all the data in one place, so you are going to need to generate a flat file anyway. Easy to read into analysis software (e.g. R) and do operations over the entire dataset
- **Cons** - very hard to manage data integrity over the long term if you are continually collecting and working with the data. Doesn't work well if you are dealing with data on a system involving many different types of objects and their relationships. Can be very difficult to carry out data querying operations

SOME TOOLS AND BUZZWORDS

- MongoDB, ArangoDB
- Document store
- JSON, YAML
- API, GraphQL
- Linked Data
- Semantic Web
- Web Ontology Language (OWL)
- Protégé

PUTTING IT INTO PRACTICE

Take a look at the conceptual model you've created for your system.

Pick one way you might want to use data or knowledge about this system.

Which type of data or knowledge model do you think is most appropriate for this system and use case?

Create an appropriate data or knowledge model from your conceptual model.

IMPLEMENTING YOUR MODEL

IMPLEMENTING YOUR MODEL

- To implement your data/knowledge model, you need to have access to **data storage and management software**.
- Access might be challenging for you, the individual, because traditionally such software runs on servers.
- Servers are good because they allows many people to access a single database at the same time, from different client programs. However, it makes it hard to 'play' with a database.
- SQLite to the rescue!

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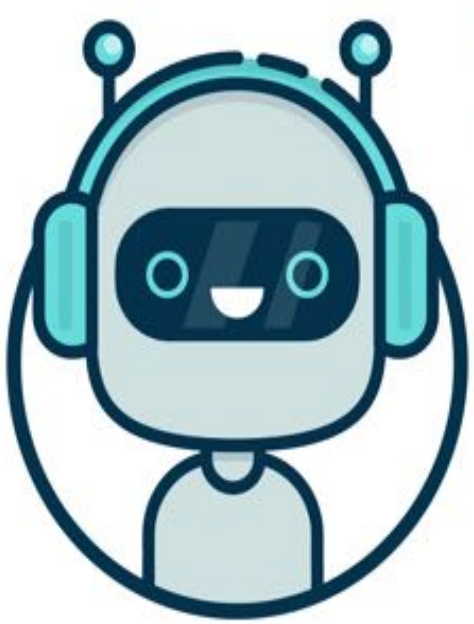
RELATIONSHIP BETWEEN PROGRAM AND DATA



ROLE OF DATA MANAGEMENT SOFTWARE

Data management software provides humans with an easy way to interact with their data.

It's essentially a human – data – interface.

Through this interface you can:

- add data to your data collection
- extract subsets of data from your collection based on certain criteria
- delete or edit data in your collection

A DATA WHAT???

Previously:

- Database
- Data warehouse
- Data Marts
- Database Management System
- (SQL)

Now:

- Data Lake
- Data Pool
- Data swamp?
- Data graveyard?
- (NoSQL)

Increasingly more of a distinction between the data store and the data management software

IN THIS COURSE: SQLITE TO THE RESCUE

SQLite is a **standalone** relational database that is installed on your Surfaces.

Let's take a quick look at the SQLite installation now!

FROM DATA MODEL TO IMPLEMENTATION

What do we do once we've completed a (logical) data model?

- instantiate the model in your chosen software (e.g. create tables in MySQL)
- load the data
- **query** the data:
  - Traditional relational databases use Structured Query Language (SQL)
  - Other types of databases use entirely different query languages (AQL, semantic engines, etc.) or rely on bespoke computer programs (e.g. written in R, Python)

DATA COLLECTION MANAGEMENT

Once you've created a data collection, you must also manage it! What does this mean? Fundamentally, it means maintaining data in the database that is:

- accurate,
- precise,
- consistent
- complete

Don't let your data lake turn into a data swamp...

EXTRAS

RELATIONAL DATABASES – DEEP DIVE

Learning how to properly structure **a relational database** is a useful skill- there are many best practices related to this.

This is beyond the scope of this course!

However, as an extra activity, you may wish to try implementing your data model in your SQLite database.

ATTRIBUTIONS AND REFERENCES

IMAGE ATTRIBUTIONS (I)

- Person with graph: https://www.flaticon.com/free-icon/person-explaining-strategy-on-a-board-with-a-sketch_38792
- Digital Signal: By Mcanet - Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=6024833
- An infrared sensor: https://commons.wikimedia.org/wiki/File:Infrared_Transceiver_Circuit.jpg#/media/File:Infrared_Transceiver_Circuit.jpg
- Server room: https://upload.wikimedia.org/wikipedia/commons/9/98/Wikimedia_Servers-0051_10.jpg
- Two bits flipped image: By Jim Salter - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=64046994
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- UML diagram of the Wikibase Data Model: https://upload.wikimedia.org/wikipedia/commons/4/4a/Wikibase_Conceptual_Data_Model.png
- Conceptual map of Free Software (Spanish): By René Mérou h(at)es.gnu.org - http://www.es.gnu.org/~reneme/mapa-conceptual-software-libre.png (http://www.es.gnu.org/), CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1377588

IMAGE ATTRIBUTIONS (II)

- Entity – Relationship Model: https://commons.wikimedia.org/wiki/File:Entity-Relationship_Model_(diagram).png
- An improved ontological representation of dendritic cells as a paradigm for all cell types: By Masci AM, Arighi CN, Diehl AD, Lieberman AE, Mungall C, Scheuermann RH, Smith B, Cowell LG -, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=7355297
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