NoSQL (Not Only SQL)

CMT220
Databases & Modelling

Cardiff School of Computer Science & Informatics
http://www.cs.cf.ac.uk

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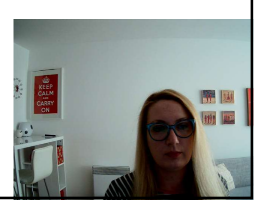
Lecture

- in this module we learnt about relational databases
- in this lecture we will learn about the latest type(s) of databases
  - NoSQL



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Big data

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Big data

- modern data collection technologies (social media, smartphones, sensors, etc.) act as force multipliers for data growth
- big data is a broad term for datasets so large or complex that traditional data processing applications (e.g. RDBMS) are inadequate
- big data project is defined by 3V + C:

1. velocity — data is streamed at an unprecedented speed and must be dealt with in near–real time
2. variety — data in various formats: structured, semi–structured and unstructured
3. volume — data that involves many terabytes or petabytes
4. complexity — data coming from multiple sources need to be connected and correlated

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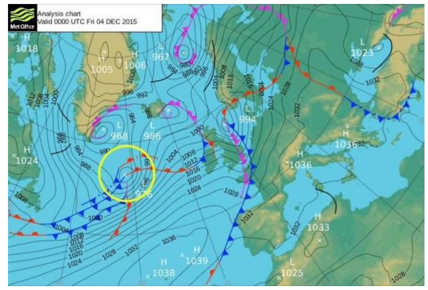
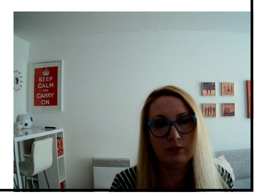
Velocity

- How fast is the data produced/processed?
- gathering data quickly is of no benefit is we analyse it once a week
- real–time analytics is about using very current data to provide information that will help improve a service or respond to demand swiftly





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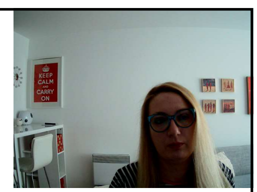
Variety



- data comes in all types of formats
  - from structured, numeric data in traditional databases ...
  - ... to unstructured text documents, email, video, audio, stock ticker data and financial transactions

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Volume

- How much data?

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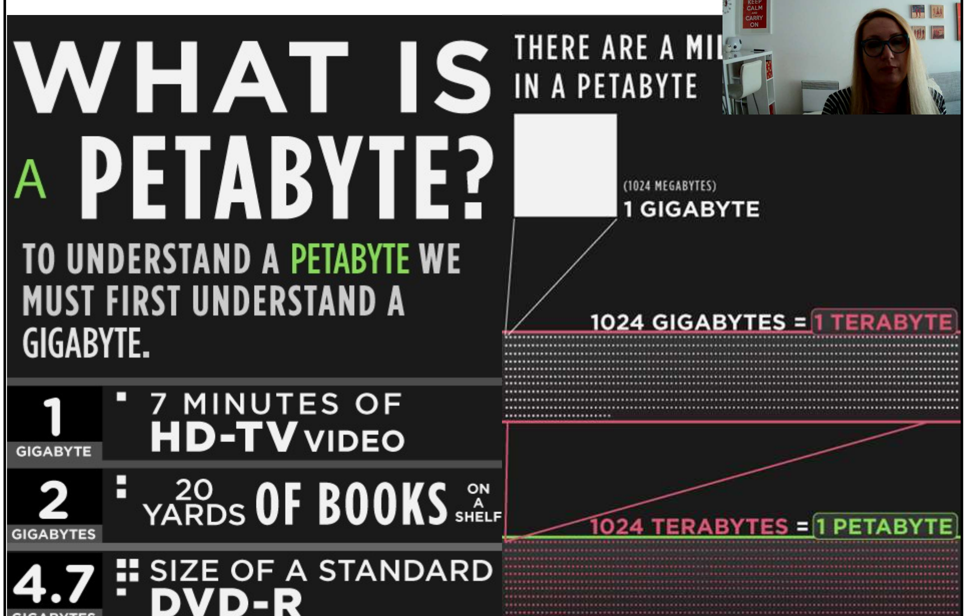

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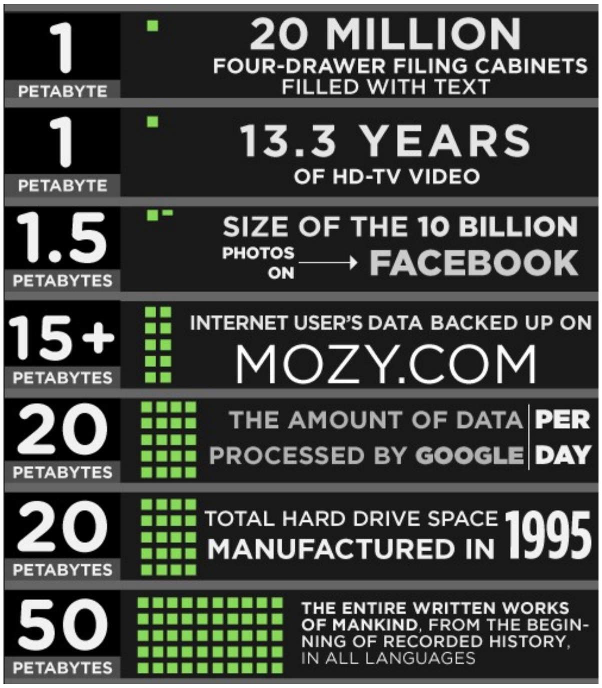

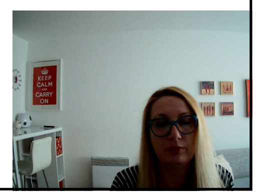

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WORLDWIDE DATACENTERS NOW ANNUALLY CONSUME

AS MUCH ENERGY AS SWEDEN

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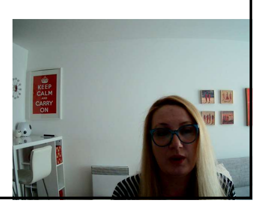

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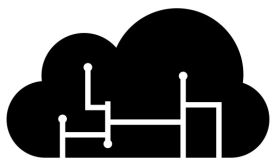
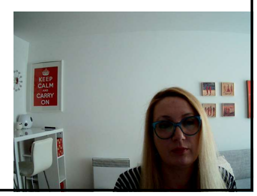
Complexity

- today's data comes from multiple sources in a variety of formats
- this makes it difficult to link, match, cleanse and transform data across systems
- however, it is necessary to connect and correlate relationships, hierarchies and multiple data linkages
- otherwise, data can quickly spiral out of control





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What is NoSQL?

- **N**ot **O**nly SQL databases AKA cloud databases, non–relational databases, Big Data databases ...
- a non–relational and largely distributed database system that enables rapid, ad–hoc organisation and analysis of extremely high–volume, disparate data types
- developed in response to the sheer volume of data being generated, stored and analysed by modern users and their applications
- NoSQL databases have become the first alternative to relational databases, with scalability, availability and fault tolerance being key deciding factors

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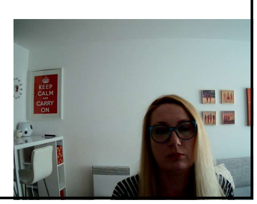
NoSQL databases

- schema–less data model
- horizontal scalability
- distributed architectures
- the use of languages and interfaces that are "not only"



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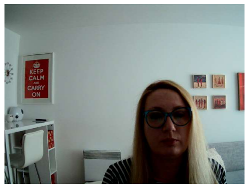
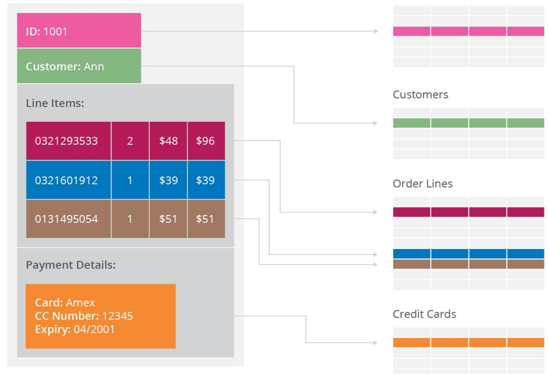
Why NoSQL?





- impedance mismatch between the relational data structures and the in–memory data structures of the application
- with NoSQL databases developers do not have to convert in–memory structures to relational structures

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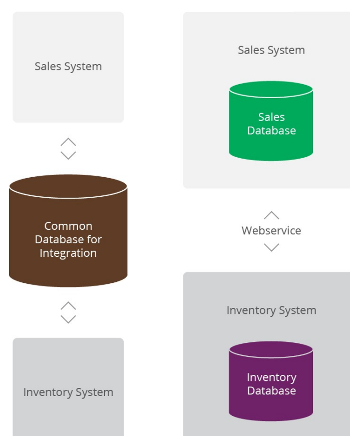
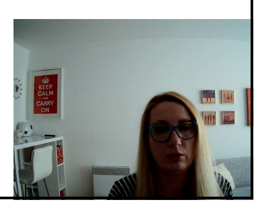
Why NoSQL?



- moving away from using databases as integration points
- encapsulating databases with applications and integrating using services instead
- the rise of the web as a platform created a vital factor change in data storage
- need to support large volumes of data by running on clusters
- relational databases were not designed to run efficiently on clusters



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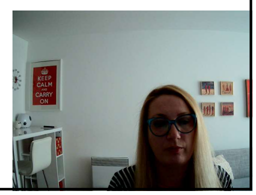
Why NoSQL?

- NoSQL technology was originally created and used by Internet leaders such as Facebook, Google, Amazon and others
- they required a DBMS that could write and read data anywhere in the world
- ... while scaling and delivering performance across massive data sets and millions of users
- today, almost every organisation has the need to deliver applications that utilise Web, mobile and IoT technologies



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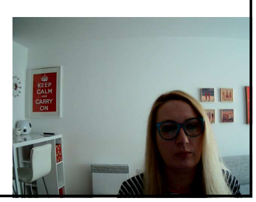
Aggregate data model

- relational data modelling is vastly different from the types of data structures that application developers use
- movement away from relational modelling and towards aggregate models
- an aggregate is a collection of data that we interact with as a unit
- the unit of data can reside on any machine and when retrieved gets all the related data along with it
- aggregates make it easier for the database to manage data storage over clusters
- ... but aggregate–oriented databases make inter–aggregate relationships more difficult to handle



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Distribution models

- aggregate–oriented databases make distribution of data easier, since all related data is contained in the aggregate
- the distribution mechanism has to move the aggregate and not have to worry about related data
- two styles of distributing data:

1. **sharding** distributes different data across multiple servers, so each server acts as the single source for a subset of data
2. **replication** copies data across multiple servers, so each bit of data can be found in multiple places

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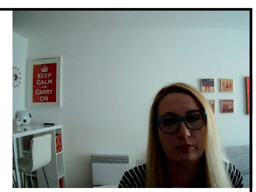
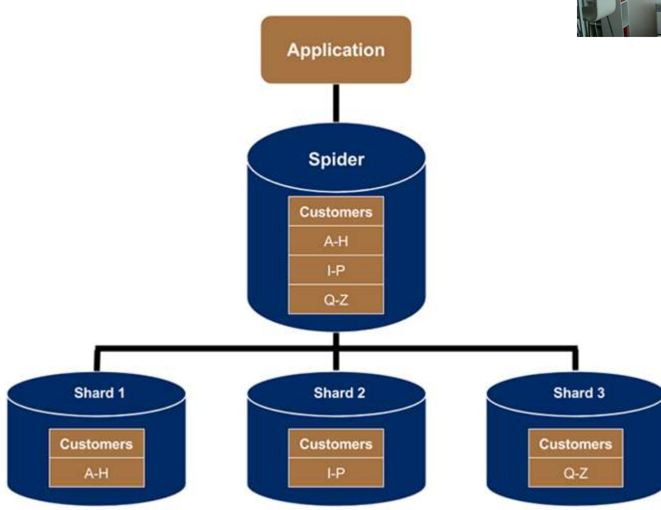
Distribution model: sharding





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Distribution model: replication

- data are copied across multiple servers
- two forms of replication:

1. master–slave replication makes one node the authoritative copy that handles writes while slaves synchronise with the master and may handle reads
2. peer–to–peer replication allows writes to any node; the nodes coordinate to synchronize their copies

- master–slave replication reduces the chance of update conflicts
- peer–to–peer replication avoids loading all writes onto a single server creating a single point of failure

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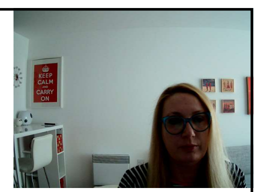
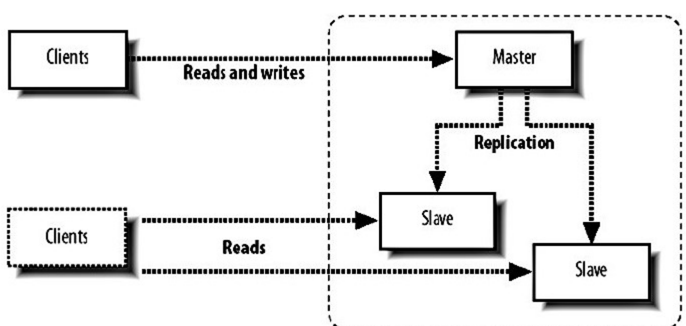
Master–slave replication





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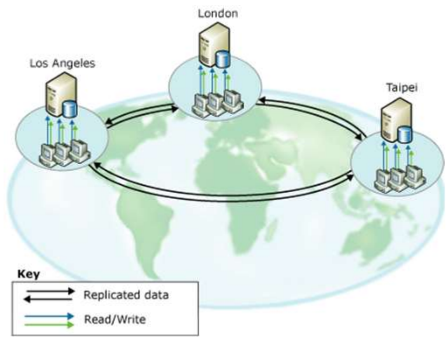
Peer–to–peer replication



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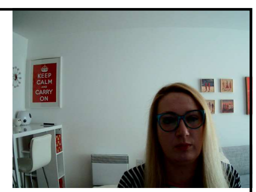
Types of NoSQL databases



1. key–value store – all data consists of an indexed key and a value
2. document database – expands on the basic idea of key–value stores
   - documents contain more complex data and each document is assigned a unique key
3. column-family store – store data tables as sections of columns of data, rather than rows of data
4. graph database – designed for data whose relations are well represented as a graph

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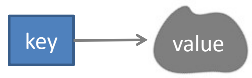
Key–value store



- simplest NoSQL database to use from an API perspective
- store data in a schema–less way
- the value is a blob that is just stored, without caring what's inside; it is the responsibility of the application to understand what was stored
- the client can either get the value for the key, put a value for a key or delete a key from the store
- key–value stores always use primary–key access, so they generally have great performance and can be scaled easily
- e.g. Memcached, Berkeley DB, Amazon DynamoDB, Couchbase

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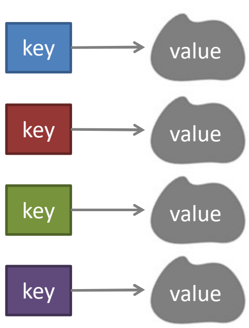
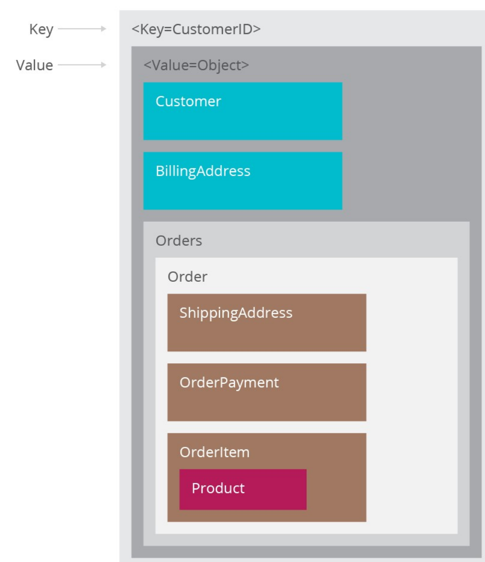
Key–value store





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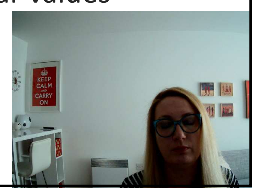
Document database

- document databases expand on the basic idea of key–value stores by storing store documents in the value part
- they store, retrieve & manage documents
  - semi–structured data
  - e.g. XML, JSON, BSON, etc.
  - self–describing, hierarchical data structures, which can consist of maps, collections and scalar values
- e.g. MongoDB, CouchDB , Terrastore, OrientDB, RavenDB



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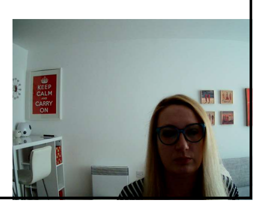
Document database

<Key=CustomerID>

```
{
   "customerid": "fc986e48ca6"
   "customer":
   {
   "firstname": "Pramod",
   "lastname": "Sadalage",
   "company": "ThoughtWorks",
   "likes": [ "Biking","Photography" ]
   }
   "billingaddress":
   { "state": "AK",
     "city": "DILLINGHAM",
     "type": "R"
    }
}
```

Key



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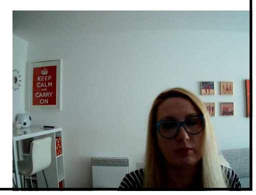
Column–family store

- AKA column store or wide–column store
- column family is a group of related data that is often accessed together
  - e.g. for a customer, we would often access their profile information at the same time, but not their orders
- column–family databases store data in column families as rows that have many columns associated with a row key
- very high performance and a highly scalable architecture
- e.g. Cassandra, HBase, HyperTable



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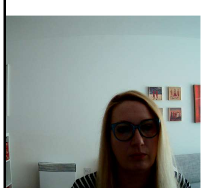
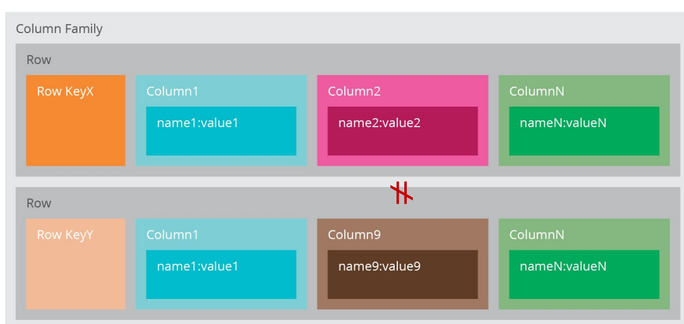
Column–family store vs. relational database





- similarity: each column family corresponds to a container of rows in a table where the key identifies the row and the row consists of multiple columns
- difference: various rows do **not** have to have the same columns, and columns can be added to any row at any time without having to add it to other rows

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Graph database

- graph databases store entities and relationships between these entities
  - entities are also known as nodes, which have properties
  - relationships are known as edges, which can also have properties
  - edges have directional significance
- the organisation of the graph lets the data to be stored once and then interpreted in different ways based on relationships
- e.g. Neo4J, Infinite Graph, OrientDB

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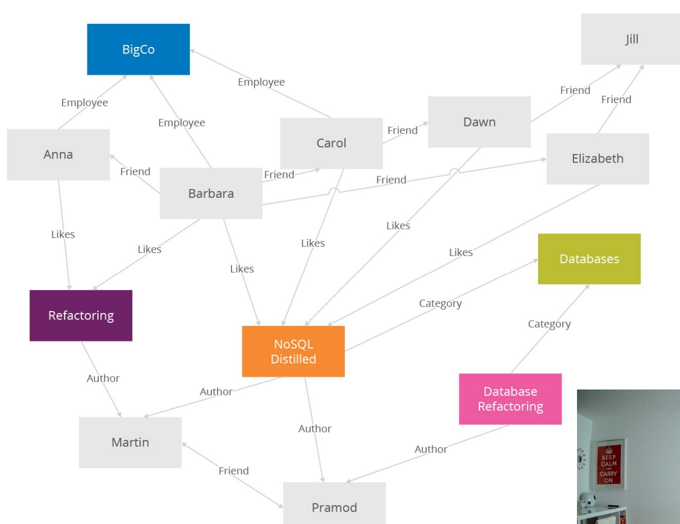
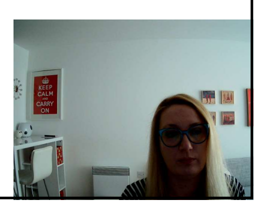
Graph database





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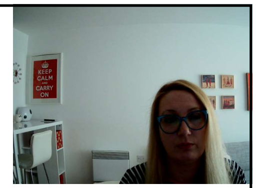
Graph database



- most of the value from the graph databases comes from the relationships and their properties
- relationships are first–class citizens in graph databases
- there is no limit on the number and types of relationships a node can have
- relationships have a type, a start node, an end node, but can also have properties of their own
- these properties can be used to query the graph
- e.g. when did they become friends, what is the distance between the nodes, what aspects are shared between the nodes, etc.

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NoSQL vs. SQL summary

	SQL databases	NoSQL databases
Types	**One** type with minor variations	**Many** different types
Development history	Developed in **1970s** to deal with the first wave of data storage applications	Developed in late **2000s** to deal with limitations of SQL databases, especially scalability, multi-structured data, geo-distribution and agile development
Examples	MySQL, PostgreSQL, Microsoft SQL Server, Oracle	MongoDB, Cassandra, HBase, Neo4j
Data storage models	Related data are stored in separate **tables**, and then joined together when more complex queries are executed.	**Varies** based on database type. Key-value stores function similarly to SQL databases, but have only two columns (key & value). Document databases store all relevant data together in single document, e.g. in JSON or XML, which can nest values hierarchically.

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Cont.	SQL databases	NoSQL databases
Schemas	Structure and data types are **fixed in advance**.	Typically **dynamic**. Applications can add new fields on the fly, and unlike SQL table rows, dissimilar data can be stored together as necessary.
Scaling 	**Vertically**, meaning a single server must be made increasingly powerful in order to deal with increased demand.	**Horizontally**, meaning that to add capacity, a database administrator can simply add more commodity servers or cloud instances. The database automatically spreads data across servers as necessary.
Development model	Mix of **open-source** (e.g. PostgreSQL, MySQL) and **closed source** (e.g. Oracle)	**Open-source**
Supports transactions	**Yes**, updates can be configured to complete entirely or not at all	In **certain circumstances** and **at certain levels** (e.g. document level vs. database level)
Data manipulation	Specific language (**SQL**) using SELECT, INSERT and UPDATE statements	Through **object-oriented APIs**
Consistency	Can be configured for **strong consistency**	**Depends** on product. Some provide strong consistency (e.g. MongoDB) whereas others offer eventual consistency (e.g. Cassandra).

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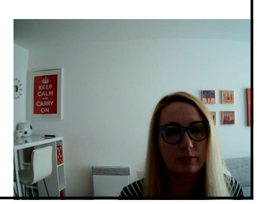
NoSQL vs. SQL databases

- designed to support different application requirements
- they typically co-exist in most enterprises
- it is **not** a question of either ... or!



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NoSQL vs. SQL databases

- key decision points on when to use which:

Use SQL when you need/have...	Use NoSQL when you need/have...
Centralised applications (e.g. business management)	**Decentralised** applications (e.g. Web, mobile and IoT)
Moderate to high availability	**Continuous** availability; no downtime
Moderate velocity data	**High** velocity data (devices, sensors, etc.)
Data coming in from **one/few locations**	Data coming in from **many locations**
Primarily **structured** data	Structured, with **semi/unstructured**
Complex/nested transactions	**Simple** transactions
Primary concern is scaling **reads**	Concern is to scale both **writes** and **reads**
Philosophy of scaling **up** for more users/data	Philosophy of scaling **out** for more users/data
To maintain **moderate** data volumes with purge	To maintain **high** data volumes; retain forever

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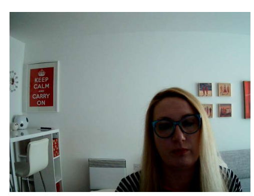
A history of databases in No–tation

- 1970: NoSQL = We have no SQL
- 1980: NoSQL = Know SQL
- 2000: NoSQL = No SQL!
- 2005: NoSQL = Not only SQL
- 2013: NoSQL = No, SQL!



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