DMIF, University of Udine

Data Management for Big Data

Introduction To NoSQL

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What is NoSQL ?

The term NoSQL (Not only SQL) refers to data stores that are **not relational databases**, rather than explicitly describing what they are.

A possible (rather general) definition: *"Next Generation DBs mostly addressing some of the points: being non-relational, distributed, open source and horizontally scalable"*.

NoSQL storage technologies have very **heterogeneous** operational, functional, and architectural characteristics.

NoSQL proposals have been developed starting from 2009 trying to address new challenges that emerged in that decade.

The Rise of NoSQL

Most enterprise level applications used to ran on top of a relational databases (MySQL, PostgreSQL, etc).

Over the years data got bigger in volume, started to change more rapidly, and to be in general more structurally varied than those commonly handled with traditional RDBMS.

As the *volume* of data increases dramatically, so does query execution time, as a consequence of the size of tables involved and of an increased number of JOIN operations (*join pain*).

Different kinds of data

We broadly distinguish between the following kinds of data:

- **Structured** data
- **Semi-structured** data
- **Unstructured** data

Structured data

Structured data can be seen as tabular data, represented by **rows** and **columns**:

- Each row belonging to a same table has a fixed format, think about an Excel file
- For instance, personal data regarding customers
- Easy to store and process by means of relational DBMSs

	A	B	C	D	E	F
1	Name	Surname	Birth date	Gender	Address	Phone number
2	John	Doe	12/07/74	M	660 North Gonzales Ave. Canyon City, CA 91387	202-555-0123
3	Mary	Jane	15/08/90	F	7772 Shore St. Zion, IL 60099	202-555-0176
4	Darell	Smart	07/03/83	M	2 Pine Ave. Royal Oak, MI 48067	202-555-0197
5	Jessica	Miller	03/11/95	F	7015 Wilson St. South Portland, ME 04106	202-555-0197
6	Belinda	Barton	05/12/67	F	22 Wakehurst Street Jackson, NJ 08527	202-555-0197
7	Ned	Fitzgerald	26/10/77	M	12 Sage Rd. Hope Mills, NC 28348	202-555-0197

Semi-structured data

Semi-structured data do not have a fixed format, but still have some structuring:

- They contain **tags** or other markers to separate semantic elements and enforce hierarchies of fields within the data
- For example, this can be the case of closed form answers given to telephone surveys

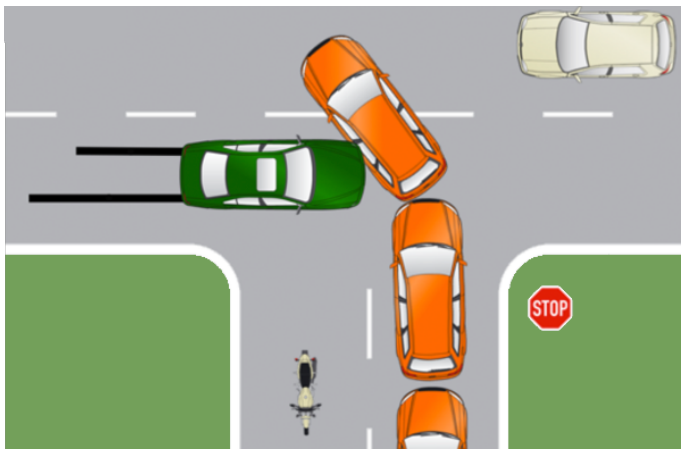
```
<Phone campaign>
    <Survey ID = 1>
        <Name> John Easter </Name>
        <Question ID = 1> yes </Question>
        <Question ID = 2> yes </Question>
        <Question ID = 2.1> 5 </Question>
        <Question ID = 2.2> 7 </Question>
        <Question ID = 3> no </Question>
    </Survey>
    <Survey ID = 2>
        <Name> Mary Christmas </Name>
        <Question ID = 1> yes </Question>
        <Question ID = 2> no </Question>
        <Question ID = 3> yes </Question>
        <Question ID = 3.1> yes </Question>
        <Note> The person seems to be rather interested in the offered product </Note>
    </Survey>
</Phone campaign>
```

Unstructured data

Unstructured data is **not organized** in any predefined manner

- Free text, e.g., natural language descriptions of accidents
- Audio and visual materials
- Difficult to store, index, and analyse

> *"Vehicle A crossed the road failing to give way to vehicle B, which subsequently hit it on its left side."*



Benefits of NoSQL

High volume and high heterogeneity data:

- RDBMS: capacity and constraints at their limits
- NoSQL are specifically designed for this scenario

Elastic Scaling:

- RDBMS scale up: bigger load $\Rightarrow$ bigger server
- NoSQL scale out: distribute data across multiple nodes, adding/removing them seamlessly

DBA Specialists:

- RDBMS require highly trained experts to monitor DB
- NoSQL require less management: automatic repair and simpler data models

Drawbacks of NoSQL

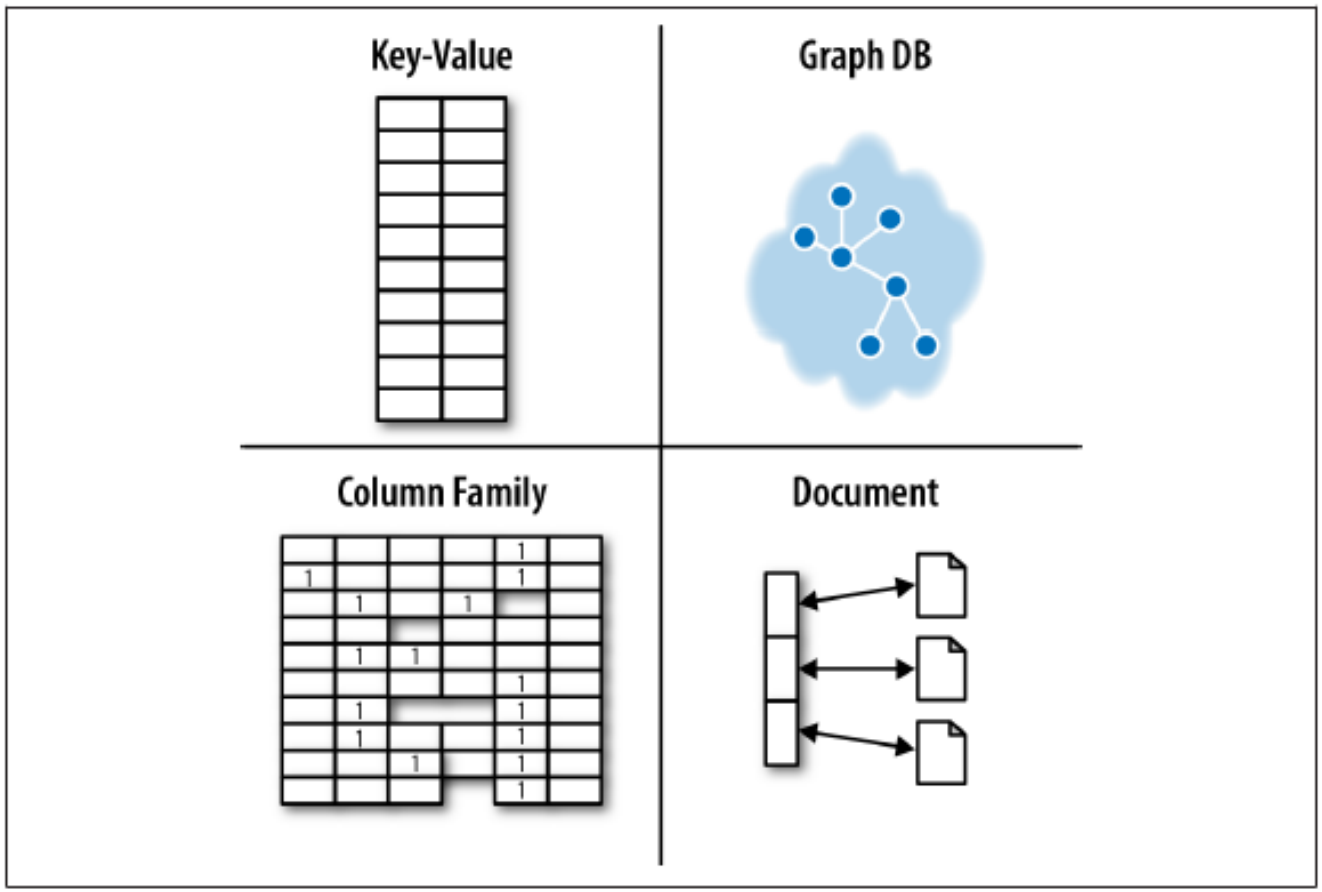
Several default constraints of RDBMS are not supported at the database level (e.g., foreign keys).

If not properly managed, the absence of a fixed structure may become an issue.

The design process is not as straightforward and consolidated as in the relational model.

Lack of SQL (though there are some SQL-inspired languages).

The NoSQL Quadrant



Key/Value Stores

Key/value stores are based on the concept of *associative array* (i.e., dictionary, or map), a data structure that contains couples of <key, values>; the key is used to access the values.

E.g., in a database storing personal data, keys could be the SSN of customers, while values their phone numbers.

Operations allowed over an associative array are:

- *Add*: add an element to the array
- *Remove*: remove an element from the array
- *Modify*: change the value associated to a key
- *Find*: search for a value by the key

Key/Value Store - Focus

Key/values stores offer just the add/remove/modify/find operations on data, which nevertheless are executed at a fixed (fast) computational cost, thanks to the associative array.

Some typical relational operations, such as complex filters and JOINS are not possible (unless a custom script is written).

Also, important RDBMS functionalities like foreign keys are not supported.

Key/value stores are very simple pertaining to to their data model, but they can be extremely sophisticated regarding horizontal scalability.

Key/Value Store - Examples

Use cases:

- Storage of profiles, preferences and configurations
- Storage of multimedia objects

Exemplary DBMSs:

- **Berkeley DB** is a high performance key/value database from Oracle Inc., with implementations in C, Java and XML/C++
- **Project Voldemort** is a (LinkedIn-born) distributed key/value store based on Berkeley DB, designed for performance and fault protection

Document-oriented Databases

Document databases store, retrieve and manage document oriented information, also known as semi-structured data.

Documents do not have a fixed structure, nonetheless they contain **tags** or other markers to separate semantic elements and enforce hierarchies of records and fields within the data. Therefore, they can be considered as a kind of **self-describing structure**.

Documents can be encoded into formats like XML and JSON.

Document stores represent a step up with respect to key-value stores, defining a structure over keys and values, thus allowing the users to operate on the internal document structure.

Document example

```
<Phone campaign>
    <Survey ID = 1>
        <Name> John Easter </Name>
        <Question ID = 1> yes </Question>
        <Question ID = 2> yes </Question>
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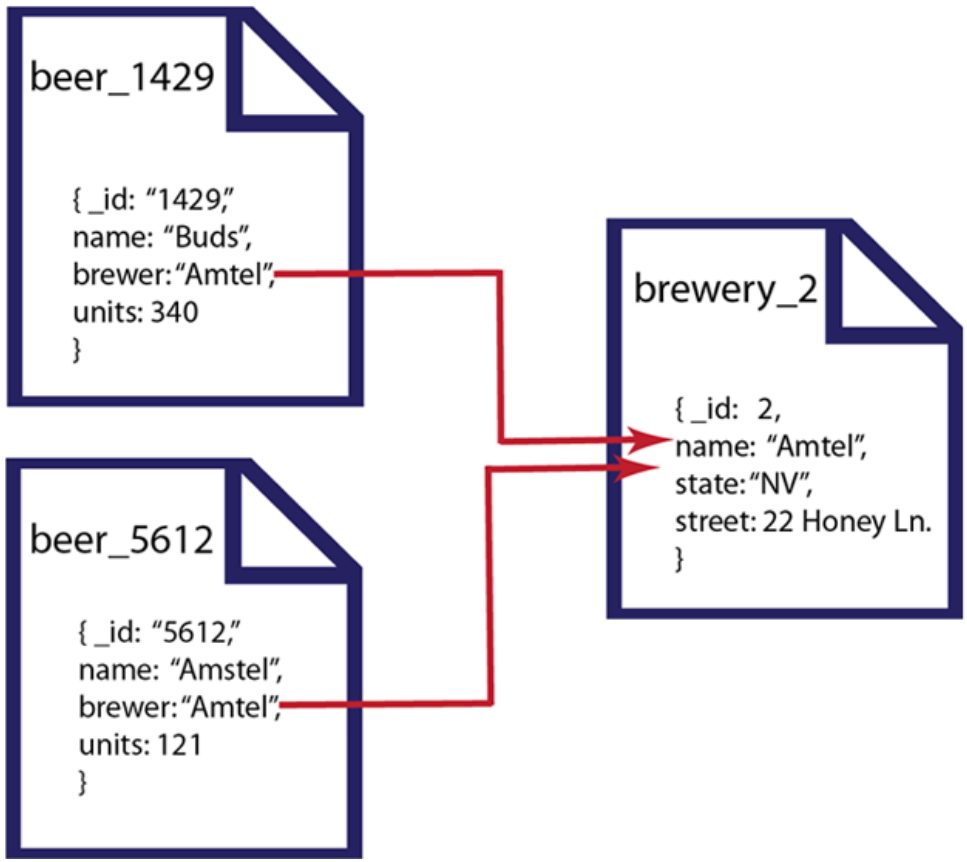
Document example



Document-oriented Databases – Operations

The core operations that a document-oriented database supports for documents are similar to other databases, and are named as CRUD:

- *Creation*: of a new document
- *Retrieval*: based on key, content, or metadata
- *Update*: the content or metadata of the document
- *Deletion*: of a document

Typical use cases: similar to key-value stores, but more complex data can be handled (product data management, inventory).

→ **MongoDB** is an example of a document-oriented database.

Column-oriented Stores

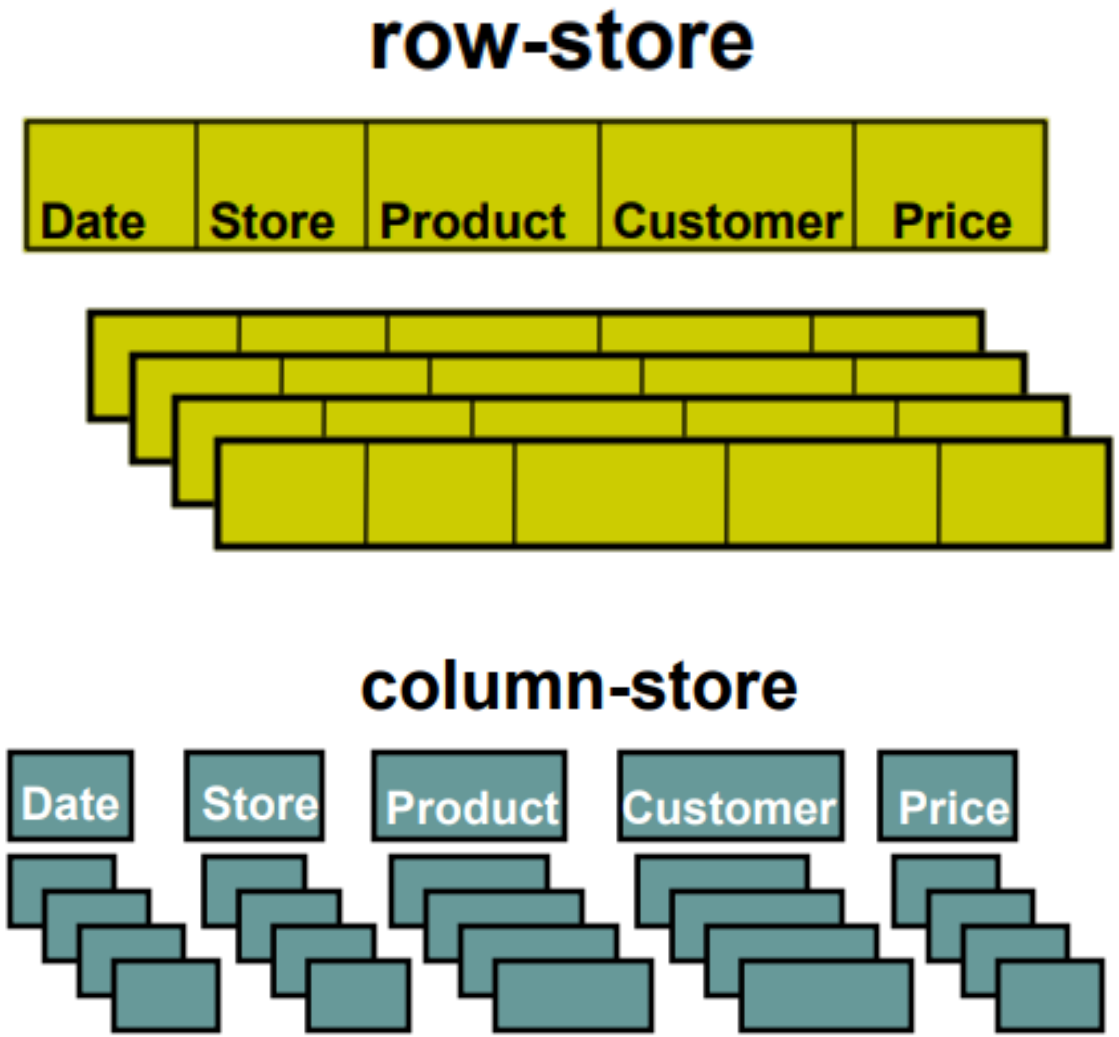
The roots of colum-store DBMSs can be traced back in the 1970s.

However, due to market needs and non favorable-technology trends it was not until the 2000s that they took off.

A column-oriented DBMS stores each database table column separately, in different disk locations, or even different machines.

Values belonging to the same column are packed together, as opposed to traditional DBMSs that store entire rows one after the other.

Rows vs Columns



Rows vs Columns

In a classical relational database each field is stored adjacent to the next in the same block on the hard drive:

```
512,Seabiscuit,Book,10.95,201712241200,goodreads.com
513,Bowler,Apparel,59.95,201712241200,google.com
514,Cuphead,Game,20.00,201712241201,gamerassaultweekly.com
```

In a columnar database, blocks on the disk for the above data might look like this:

```
512,513,514
Seabiscuit,Bowler,Cuphead
Book,Apparel,Game
10.95,59.95,20.00
201712241200,201712241200,201712241201
goodreads.com,google.com,gamerassaultweekly.com
```

Column Store Pros

Column stores are beneficial when the typical application is reading a subset of columns, or performing **aggregate functions** over them (AVG, MIN, MAX, . . .).

They offer efficient storing capabilities due to an easier **compression of data**, which is performed by column (columns have a low information entropy).

Columnar databases are **very scalable**, and well suited for *massively parallel processing* (MPP), which involves having data partitioned and spread across a large cluster of machines.

Column Store Cons

The main drawbacks of column-based stores are related to write operations and tuple (re)construction.

Newly inserted tuples have to be **broken down** to their component attributes, and each attribute must be written separately.

Also tuple construction is considered problematic, since information about a logical entity is stored in multiple locations, which brings an **overhead** for queries that access many attributes from an entity.

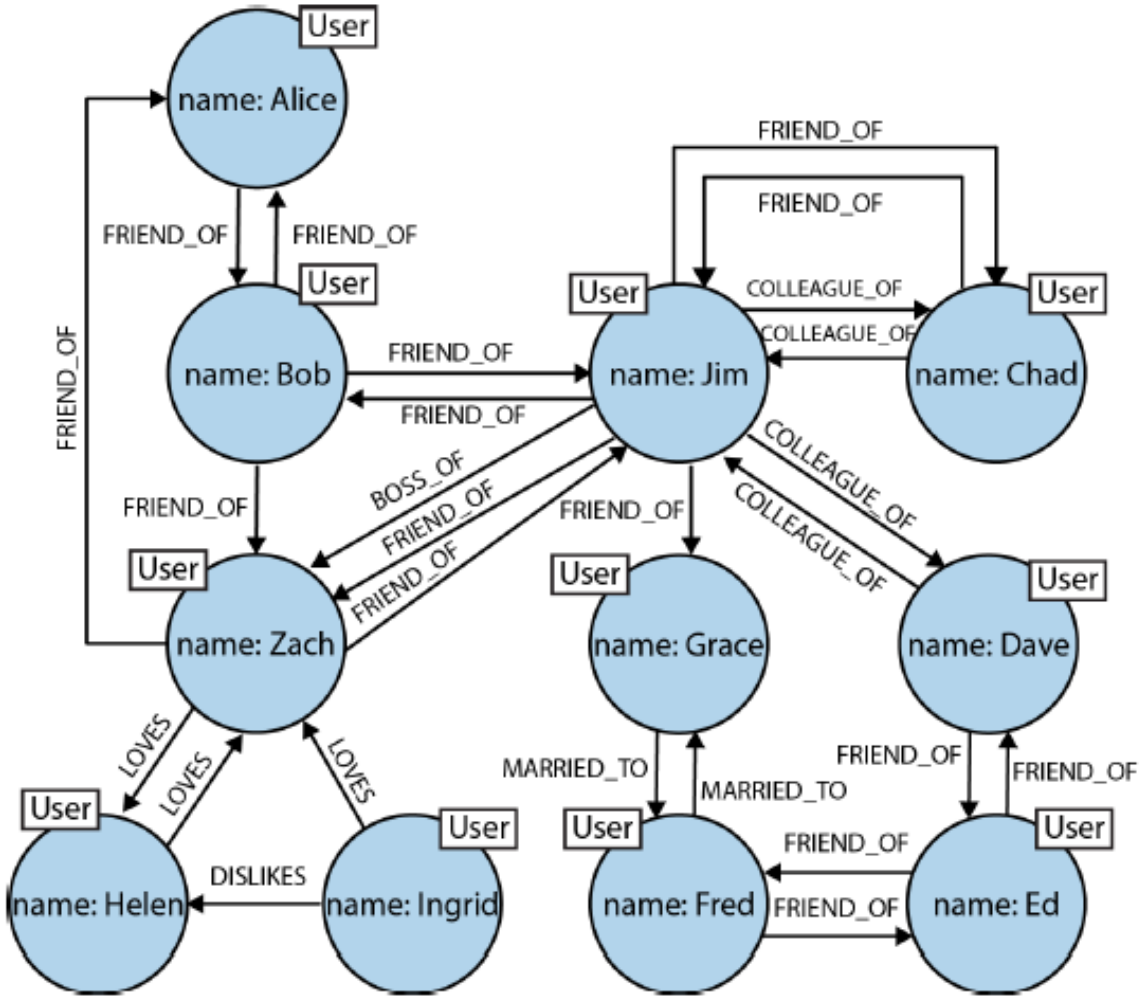
→ **Cassandra** is an example of a column store database.

Graph Databases

A graph database is a database that uses graph structures for semantic queries with *nodes* (possibly of different kinds), *edges*, and *properties* to represent and store data.

Graph databases can naturally represent certain kinds of semi-structured, **highly interconnected data**, such as those present in social networks, or in geospatial and biotech applications.

Graph Example



Graph Databases – Why

Of course, the previous graph could be modeled using other kinds of NoSQL approaches, as well as RDBMSs.

Nevertheless, the resulting databases would be very difficult to query, update, and populate.

On the contrary, graph databases can easily answer to queries such as:

- what is the shortest path connecting node *X* with node *Y*?
- what are the friends of *Billy*?
- what are the friends of friends of *Billy*?

In native implementations, nodes have **direct pointers** connecting them, so the navigation time is independent from the graph size.

Examples of Graph Databases

Neo4J is a very performing, native, open source property graph database that guarantees ACID properties offering scalability up to billions of nodes.

AllegroGraph is a closed source triplestore, designed to store RDF triples; it supports ACID properties.

ArangoDB is a multi-model, open source, database system that supports three data models (key/value, documents, graphs).

Apache Giraph, originally developed by Yahoo and later donated to the Apache Foundation.

Bibliography

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