

CSCI235 Database Systems

NoSQL Database Systems

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NoSQL Database Systems

Outline

NoSQL database system ? What is it ?

What is in the name "NoSQL" ?

Why NoSQL database systems ?

Properties of NoSQL database systems

NoSQL database system ? What is it ?

NoSQL database systems were developed in early 2000s in a response to the demands for processing of vast amounts of data produced by increasing Internet usage and mobile geo-location technologies

Traditional solutions were either too expensive, not scalable, or required too much time to process data

Modern **NoSQL database systems** "borrowed" some of the solutions from the earlier systems and made significant advances in scalability and efficient processing of diverse types of data such as text audio, video, image, and geo-location

NoSQL database systems include the following types of database systems categorized by a logical view of data provided: **key-value stores**, **document stores**, **graph stores**, **column stores**

NoSQL Database Systems

Outline

[NoSQL database system ? What is it ?](#)

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[Why NoSQL database systems ?](#)

[Properties of NoSQL database systems](#)

What is in the name "NoSQL"?

A term "NoSQL" has been used for the first time in late 1990 by C. Strozzi as a name of open-source relational database system that did not use SQL as a query language

The usage of "NoSQL" as it is recognized today has been used by J. Oskarsson in 2009 for the projects experimenting with alternate data storage, like BigTable (Google) and Dynamo (Amazon)

"NoSQL" database systems do not use SQL, run on the clusters of computers and provide different options for consistency and distribution

Despite its confrontational nature some people say that "NoSQL" means "Not Only SQL", but ... then it should be written as "NOSQL" and it is not

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[NoSQL database system ? What is it ?](#)

[What is in the name "NoSQL" ?](#)

[Why NoSQL database systems ?](#)

[Properties of NoSQL database systems](#)

Why NoSQL database systems ?

Data model: A **tabular view** of data is not convenient for **hierarchical** and **network** database domains

Impedance mismatch problem: A **tabular view** of persistent data is not consistent with a transient view of data in **object-oriented programming languages**

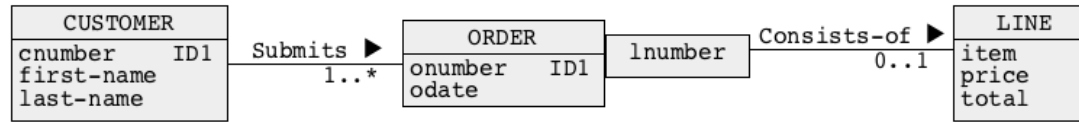
Application and integration of database systems: A structure that integrates many applications is more complex than single application requires, for example an index required by one application may cause performance problems for another application

Clusters of small computers: Relational databases that operate on the shared persistent storage subsystems are not designed to work well on the clusters of small computers

Distribution and consistency: **ACID** based transaction protocols are too strict for distributed transaction (see previous presentation)

Why NoSQL database systems ?

Data model: A **tabular view** of data is not convenient for **hierarchical** and **network** database domains



Logical design provides the following relational schemas:

CUSTOMER(cnumber, first-name, last-name)
PRIMARY KEY = (cnumber)

ORDERS(onumber, odate, cnumber) **PRIMARY KEY** = (onumber)
FOREIGN KEY = (cnumber) **REFERENCES** CUSTOMER(cnumber)

LINE(onumber, lnumber, item, price total)
PRIMARY KEY = (onumber, lnumber)
FOREIGN KEY = (onumber) **REFERENCES** ORDERS(onumber)

Relational schemas

A query, that finds total amount of money spent by each customer requires join of three relational tables

Why NoSQL database systems ?

Impedance mismatch problem: A **tabular view** of persistent data is not consistent with a transient view of data in **object-oriented programming languages**

Consider the relational tables

```
DOCUMENT(title, class, edate)
```

DOCUMENT schema of relational table

```
ACCESS(user, class)
```

ACCESS schema of relational table

A query **Find all documents available to a given user** is implemented as the following **SELECT** statement

```
SELECT title
FROM DOCUMENT JOIN ACCESS
      ON DOCUMENT.class = ACCESS.class
WHERE user = ...;
```

SELECT statement

SQL query optimizer is able to pick an appropriate algorithm for implementation of join operation

Why NoSQL database systems ?

Object-oriented programming forces **encapsulation of object classes**

Encapsulation of objects classes forces **one object at a time** technique of object processing

```
class Document{ String title;  
                String className;  
                Date edate )
```

Document class

```
class Access( String user,  
              String className)
```

Access class

A query find all documents available to a user is implemented as

```
for(a in Access)  
  for( d in Document)  
    if a.user = ... and d.className = a.className then  
      out(d.title);
```

Object oriented implementation of a query

Why NoSQL database systems ?

In **object-oriented view**, join is performed by an application and not by a database server

One object at a time technique of object processing forces **nested loop** implementation of join operation

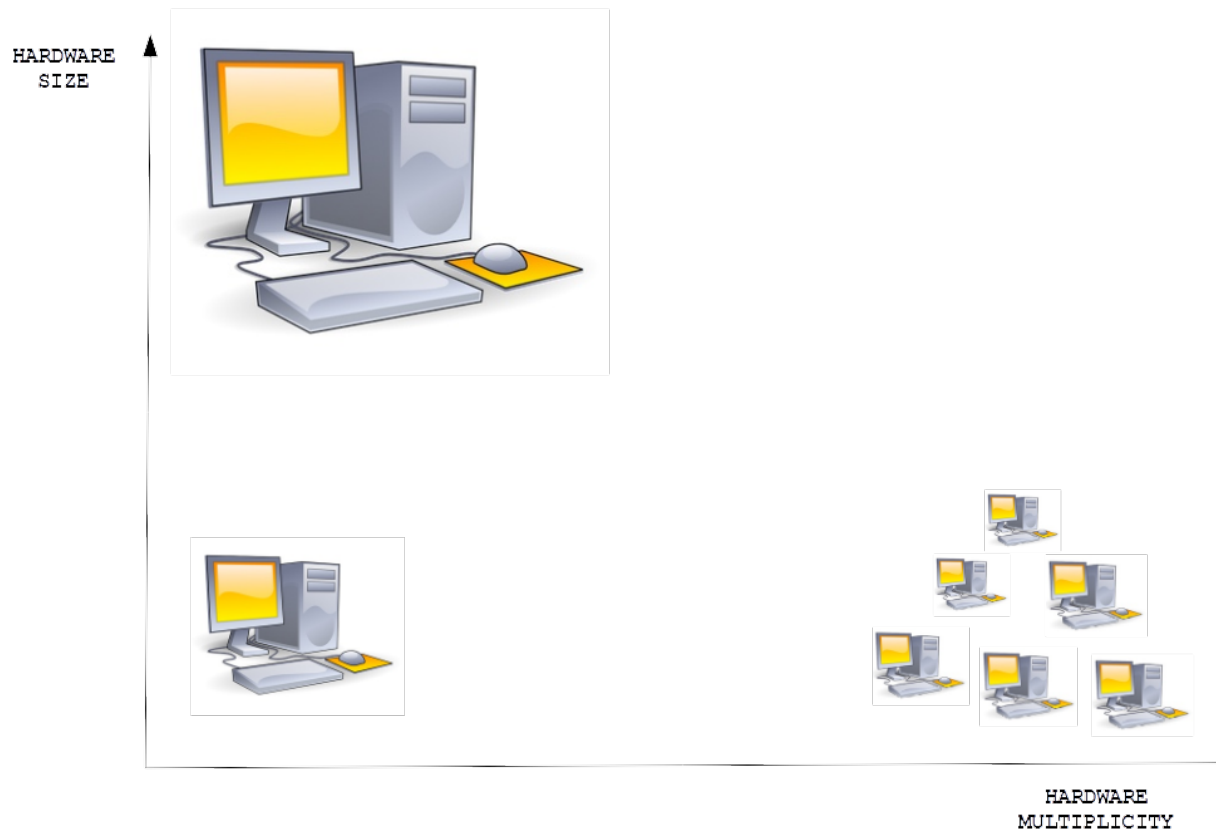
When **object-oriented application** is processed remotely from a database systems the relational tables must be **transmitted to a remote site**

Database application programmers should directly access a bulk object (e.g. a collection of the documents) instead of forming the member objects individually and grouping them into a bulk object inside an application code

A query must be **stored at** and it must be **processed by** a **database server**

Why NoSQL database systems ?

Clusters of small computers: Relational databases that operate on the shared persistent storage subsystems are not designed to work well on the clusters of small computers



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[NoSQL database system ? What is it ?](#)

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- Semistructured, unstructured data, and schemaless data model
- Specialized distribution models
- Weak consistency
- Relaxing durability
- Versioning

Semistructured, schemaless data model

Semistructured data is a form of structured data that does not conform to the formal structure of data models associated with relational databases or other forms of data tables

Semistructured data contains tags or other markers to separate semantic elements and enforce hierarchies of records and fields within the data

Schemaless data model means that no particular data structure is used to store data in a database

Schemaless database does not require consistency with a rigid schema, e.g. database schema, relational schema, data type, table, etc.

Schemaless database does not enforce data type limitations on individual values

Schemaless database can **store structured** and **semistructured data**

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Specialized distribution models

Single server: means no distribution at all

Sharding: to support horizontal scalability we put different parts of data onto different servers (**shards**)

Data distribution leads to two **data replication modes**:

- **Master-slave replication:** data are replicated across multiple nodes and one node is designated as master node, the others are slaves; all updates are made to the master and later on propagated to slaves
- **Peer-to-peer replication:** data replicated across multiple nodes; all replicas have the same weight, no master mode; nodes communicate their writes; all nodes read and write all data

Combining sharding and replication: use both master-slave replication and sharding

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Weak consistency

A typical **read consistency** principle where update is performed over two or more data items blocks access to all data items affected by the update, for example in **2PL** protocol

NoSQL database systems relax the **strict transactional consistency** to some extent

In a new model of consistency, data items can be left inconsistent over certain period of time called as **inconsistency window**

A concept of **eventual consistency** is used to enforce **replication consistency** over distributed and replicated data items

Eventual consistency means that the copies of data items can be inconsistent in **inconsistency window** and all copies will have the same value later on

Weak consistency

Different domains have different **tolerances for inconsistencies** and we have to take this tolerance into account as make our decisions

Even in traditional relational database systems it is possible to relax consistency from the highest isolation level (**serializable**) to the lowest levels (**read-committed**) to get better performance

CAP theorem: Out of three properties of **Consistency**, **Availability**, and **Partition tolerance** you can get only two

Consistency: A state of a database satisfies the given consistency constraints at any moment in time

Availability: If you can talk to a node in a cluster then it can read and write data

Partition: Cluster can survive communication breakages that separate the cluster into multiple partitions unable to communicate with each other (**split brain**)

Weak consistency

A single server system is **CA** because it has **Consistency** and **Availability** and not **Partition** tolerance

If a cluster must be tolerant of network partitions, then we have to trade consistency for availability

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Relaxing durability

If SQL systems follow **ACID** properties then NoSQL systems follow **BASE** properties: **Basically Available**, **Soft** state, **Eventually** consistent

Relaxing durability means that we trade of durability for higher performance, for example, apply updates to **in-memory representation of a database** and periodically flush changes to disk

Another class of **durability tradeoffs** comes with replicated data, for example, when a node processes and update but fails before that updates is replicated to other nodes

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Versioning

A **version** is a particular form of something differing in certain respects from an earlier form or other forms of the same type of thing

Versioning in a database systems means that all modifications of data items are stored in a database together with timestamps when such modifications occurred

In practice **versioning** is performed to a predefined **depth**, i.e. a total number of versions of data item is determined when a data item is created

Versioning allows for representation of historical information

Numbering of **data versions** through **timestamps** allows to track when a data item has changed and if a new version is available allows to determine specifically which version is the most current one

References

Harrison G., Next Generation Databases, NoSQL, NewSQL, Big Data, Apress, 2015