NoSQL Overview & MongoDB Basics

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Some slides were adopted from S. Davidson and Z. Ives with permission

Leaning Objectives

After this lecture, we will:

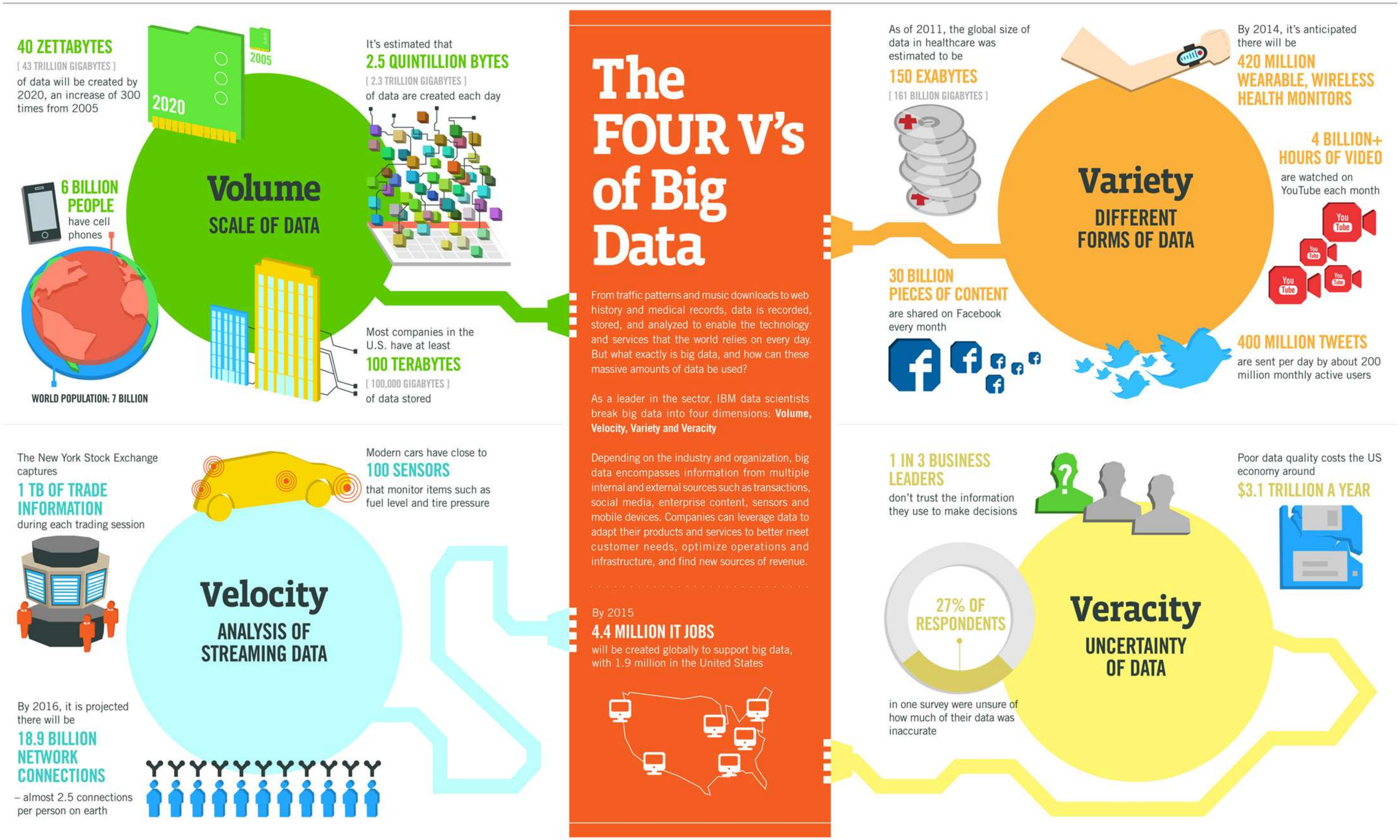
- Introduce the NoSQL paradigm
- Discuss the trade-offs between relational and non-relational(NoSQL) databases
- Introduce MongoDB, a document-oriented database
- Learn MongoDB simple queries.

The evolution of data models

- Hierarchical (IBM IMS) – 60's-70's
- Network, CODASYL (Backman, IDS) – 60's
- Relational – 70's
- Object-relational (Stonebraker, et al) – 90's
- OODBMS (Atkinson, et al) – 90's
- Array databases (MonetDB, SciDB, …) – 90's
- XML (document-oriented) – 2000's
- **NoSQL – 2010's**
- NewSQL – 2011-present

Why NoSQL?

- Databases are no longer one-size-fits-all
- The needs of modern applications do not always match what relational databases provide.
- Every large web platform (e.g. Google, Facebook, LinkedIn) has developed some sort of custom solution to scale.



Sources: McKinsey Global Institute, Twitter, Cisco, Gartner, EMC, SAS, IBM, MEPTEC, QAS

IBM

“Big Data” is two problems

- The **analysis** problem
  - How to extract useful info, using modeling, ML and stats.
- The **storage** problem
  - How to store and manipulate huge amounts of data to facilitate fast queries and analysis
- Problems with traditional (relational) storage
  - Not flexible
  - Hard to partition, i.e. place different segments on different machines
- NoSQL solutions address these problems.

Need for flexibility: E-Commerce

- **Problem:** Product catalogs store different types of objects with different sets of attributes.
- This is not easily done within the relational model, need a more "flexible schema"
- **Relational Solutions**
  - Create a table for each product category
  - Put everything in one table
  - Use inheritance
  - Entity-Attribute-Value
  - Put everything in a BLOB

RDBMS (1): Table per Product

```
CREATE TABLE `product_audio_album`
  ( `sku` char(8) NOT NULL, ...
    `artist` varchar(255) DEFAULT NULL,
    `genre_0` varchar(255) DEFAULT NULL,
    `genre_1` varchar(255) DEFAULT NULL, ...
    PRIMARY KEY(`sku`)) ...
CREATE TABLE `product_film`
  ( `sku` char(8) NOT NULL, ...
    `title` varchar(255) DEFAULT NULL,
    `rating` char(8) DEFAULT NULL, ...
     PRIMARY KEY(`sku`)) ...
```

RDBMS (2): Single table for all

```
CREATE TABLE `product`
  ( `sku` char(8) NOT NULL, ...
    `artist` varchar(255) DEFAULT NULL,
    `genre_0` varchar(255) DEFAULT NULL,
    `genre_1` varchar(255) DEFAULT NULL, ...
    `title` varchar(255) DEFAULT NULL,
    `rating` char(8) DEFAULT NULL, ...
    PRIMARY KEY(`sku`))
```

RDBMS (3): Inheritance

```
CREATE TABLE `product`
    ( `sku` char(8) NOT NULL,
      `title` varchar(255) DEFAULT NULL,
      `description` varchar(255) DEFAULT NULL,
      `price`, ...
       PRIMARY KEY(`sku`))
CREATE TABLE `product_audio_album`
    ( `sku` char(8) NOT NULL, ...
       `artist` varchar(255) DEFAULT NULL,
       `genre_0` varchar(255) DEFAULT NULL,
       `genre_1` varchar(255) DEFAULT NULL, ...
        PRIMARY KEY(`sku`),
        FOREIGN KEY(`sku`) REFERENCES `product`(`sku`))
….
```

RDBMS (4): Entity Attribute Value

Entity	Attribute	Value
sku_ooe8da9b	Type	Audio Album
sku_ooe8da9b	Title	A Love Supreme
sku_ooe8da9b	…	…
sku_ooe8da9b	Artist	John Coltrane
sku_ooe8da9b	Genre	Jazz
sku_ooe8da9b	Genre	General

NoSQL solution: flexible schema

- **"Key-value store"**

```
{ sku: "00e8da9b",
  type: "Audio Album",
  title: "A Love Supreme",
  description: "by John Coltrane",
  shipping: { weight: 6,
        dimensions: { width: 10, height: 10, depth: 1 } },
  pricing: { list: 1200, retail: 1100, savings: 100},
  details: { title: "A Love Supreme [Original Recording]",
              artist: "John Coltrane",
              genre: [ "Jazz", "General" ]}
}
```

The analysis problem…

- So far, we've focused on the storage problem – flexible schemas. There is also the analysis problem, which requires scalability.
- Relational databases typically scale by getting bigger servers
  - Scaling across multiple servers is complicated
- NoSQL solutions are all about scaling across multiple servers (e.g. cloud instances)
  - Data can be automatically distributed across nodes/servers
  - "Map-reduce" spreads computation across a cluster

Types of NoSQL solutions

- **Key-value stores:**
- **Column-oriented:**
- **Document:**
- **Graph:** Neo4J

Outline

- ✓ NoSQL Introduction
- Relational-NoSQL Trade-offs
- MongoDB
  - Model and simple queries

Relational-NoSQL Trade-offs

Fundamentally, there are several different trade-offs

- Schema vs. no schema
  - Schema ➔ performance, no schema ➔ flexibility but parse overhead (can have partial schemas like in XML)
- Replication, data partitioning
  - Replicas mean faster queries, slower (consistent) updates
- Level of abstraction
  - High-level queries – parsing, optimization, etc. – vs. low-level operations
- Consistency
  - What does the database do on concurrent updates, especially when distributed?

Consistency and NoSQL

- When an object is updated from different sites or in different transactions, what happens?
- Eventual consistency
  - "Eventually the latest write will be the winner, and every write has an option to see if the data has changed while it was busy"
- Relational-style DBMSs generally have stronger options, like serializability

Outline

- ✓ NoSQL Introduction
- ✓ Relational-NoSQL Trade-offs
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Overview of mongoDB

- MongoDB is an example of a document-oriented NoSQL solution
- The query language is limited, and oriented around "collection" (relation) at a time processing
- The power of the solution lies in the distributed, parallel nature of query processing
  - Replication and sharding

MondoDB Data Model

- A MongoDB deployment hosts several databases
  - A database holds a set of collections
    - A collection holds a set of documents
      - A document is a set of key-value pairs

RDBMS	MongoDB
Table	Collection
Row(s)	JSON Document
Index	Index
Join	Embedding & Linking
Partition	Shard
Partition Key	Shard Key

Basic data types

- Null
- Boolean
- Integer (32- and 64-bit)
- Floating point
- String
- Date
- ObjectId
- Code (JavaScript)
- Array
- Embedded document

Sample Document

```
mydoc = {
  _id: 1,
  name: { first: "John", last: "Backus" },
  birthyear: 1924,
  contribs: [ "Fortran", "ALGOL", "Backus-Naur Form", "FP" ],
  awards: [ { award_id: "NMS001",
              year: 1975 },
            { award_id: "TA99",
              year: 1977} ]
         }
```

Always indexed, automatically assigned unless provided

Array of documents

Core MongoDB operations

- CRUD: *create*, *read*, *update*, and *delete*
- Insert
  - One at a time: db.people.insert(mydoc)
  - New (version 3.2):
    db.collection.insertOne(),
    db.collection.insertMany()
- Delete
  - Documents that match some predicate, e.g. to remove the document in the previous slide:
    db.people.deleteOne({"_id": 1})
    db.people.deleteMany({birthyear: 1924})
  - All documents in a collection: db.people.deleteMany()
    - The collection still remains, with indexes
  - Remove a collection (faster): db.people.drop()

Core MongoDB operations, cont.

- Update documents in a collection
  - db.collection.updateOne(), db.collection.updateMany()

```
db.people.updateMany( {birthyear: 1924}, {$set: {birthyear: 1925}})
db.people.updateMany( {birthyear: 1924}, {$set: {type: “Deceased”}})
```

  - $rename operator: change property name.

```
db.people.update({}, { $rename : {“birthyear": “birth" }})
```

Querying

- Use find( ) function and a query document
- Ranges, set inclusion, inequalities using $ conditionals
- Complex queries using $where clause
- Queries return a database cursor
- Meta-operations on cursor include skipping some number of results, limiting the number of results returned, sorting results.

Another sample document

```
d={
    _id : ObjectId("4c4ba5c0672c685e5e8aabf3"),
    author : "Kevin",
    date : new Date("February 2, 2012"),
    text : "About MongoDB...",
    birthyear:  1980,
    tags : [ "tech", "databases" ]
    }

> db.posts.insert(d)
```

Find

Return entire collection in posts:

```
db.posts.find( )
```

Return posts that match condition (conjunction):

```
db.posts.find({author: “Kevin”, birthyear: 1980})
```

```
{ _id : ObjectId("4c4ba5c0672c685e5e8aabf3"), author : "Kevin",
date : Date(“February 2, 2012”), birthyear:  1980,
 text : "About MongoDB...",  tags : [ "tech", "databases" ]}
```

“Pretty” format

- If you want to be able to read the result:

```
db.posts.find({author: “Kevin”,  birthyear: 1980}).pretty()
```

```
{
    _id : ObjectId("4c4ba5c0672c685e5e8aabf3"),
    author : "Kevin",
    date : Date(“February 2, 2012”),
    birthyear:  1980,
    text : "About MongoDB...",
    tags : [ "tech", "databases" ]
}
```

Specifying which keys to return

```
db.people.find({}, {name:1, contribs:1})
```

```
{
   _id: 1,
   name: { first: "John", last: "Backus" },
   contribs: [ "Fortran", "ALGOL", "Backus-Naur Form", "FP" ]
}
```

```
db.people.find({}, {_id: 0, name:1})
```

```
{
   name: { first: "John", last: "Backus" }
}
```

Ranges, Negation, OR-clauses

- Comparison operators: $lt, $lte, $gt, $gte
  - db.posts.find({birthyear: {$gte: 1970, $lte: 1990}})
- Negation: $ne
  - db.posts.find({birthyear: {$ne: 1982}})
- Or queries: $in (single key), $or (different keys)
  - db.posts.find({birthyear: {$in: [1982, 1985]}})
  - db.posts.find({$or: [{birthyear: 1982}, {author:"John"}], name:"abdu"})

Arrays

- db.posts.find({tags: "tech"})
  - Print complete information about posts which are tagged "tech"
- db.posts.find({tags: {$all: ["tech", "databases"]}}, {author:1, tags:1})
  - Print author and tags of posts which are tagged with both "tech" and "databases" (among other things)
  - Contrast this with:

  db.posts.find({tags: ["databases", "tech"]})

Querying Embedded Documents

- db.people.find({"name.first": "John"})
  - Finds all people with first name John
- db.people.find({"name.first": "John", "name.last": "Smith"})
  - Finds all people with first name John and last name Smith.
  - Contrast with

  db.people.find({"name": {"first": "John", "last": "Smith"}})

Sample Document

```
mydoc = {
  _id: 1,
  name: { first: "John", last: "Backus" },
  birthyear: 1924,
  contribs: [ "Fortran", "ALGOL", "Backus-Naur Form", "FP" ],
  awards: [ { award_id: "NMS001",
              year: 1975 },
            { award_id: "TA99",
              year: 1977} ]
        }
```

Summary

- NoSQL solutions address the needs of modern applications
- MongoDB is an example of a document-oriented solution
  - The query language is oriented around "collection" at a time processing
- The power of many of these solutions lies in the distributed, parallel nature of query processing
  - Replication and sharding