MongoDB and NoSQL Databases

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"campus": "Byblos",
"semester": "Fall 2017",
"instructor": "Haidar Harmanani"
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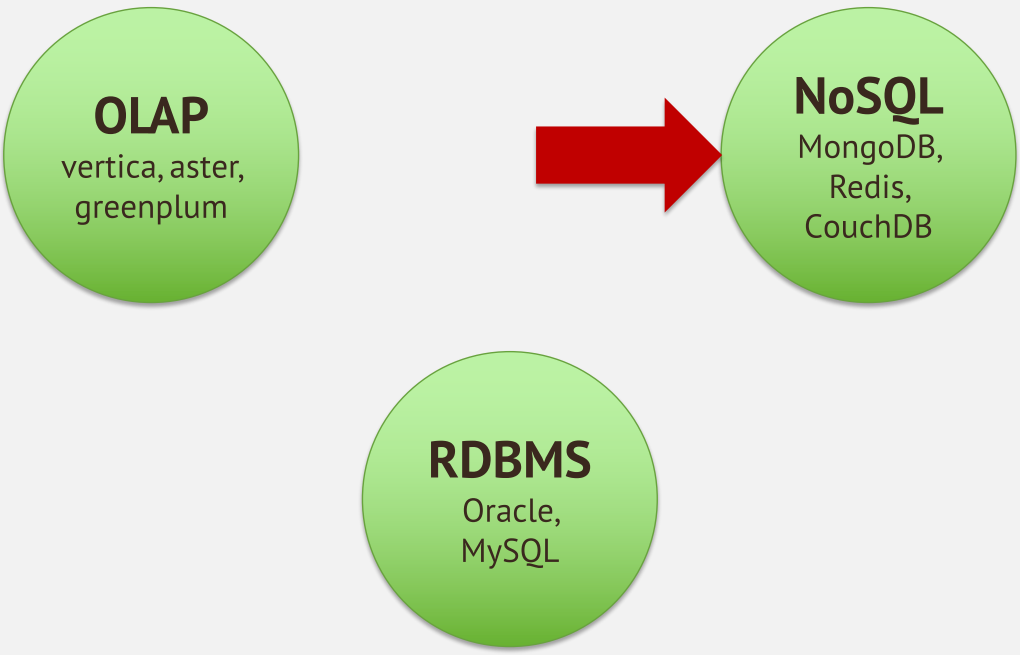
A look at the Database Market



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What is NoSQL Database?

- Work extremely well on the web
- NoSQL (cloud) databases
  - Use document-based model (non-relational)
  - Schema-free document storage
    - Still support indexing and querying
    - Still support CRUD operations (create, read, update, delete)
    - Still supports concurrency and transactions
    - No joins
    - No complex transactions
  - Horizontally scalable
  - Highly optimized for append / retrieve
  - Great performance and scalability
  - NoSQL == “No SQL” or “Not Only SQL”?

Relational vs. NoSQL Databases

- Relational databases
  - Data stored as table rows
  - Relationships between related rows
  - Single entity spans multiple tables
  - RDBMS systems are very mature, rock solid
- NoSQL databases
  - Data stored as documents
  - Single entity (document) is a single record
  - Documents do not have a fixed structure

Relational vs. NoSQL Models

Relational Model

Name	Svetlin Nakov
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*
1

Street	Al. Malinov 31
Post Code	1729

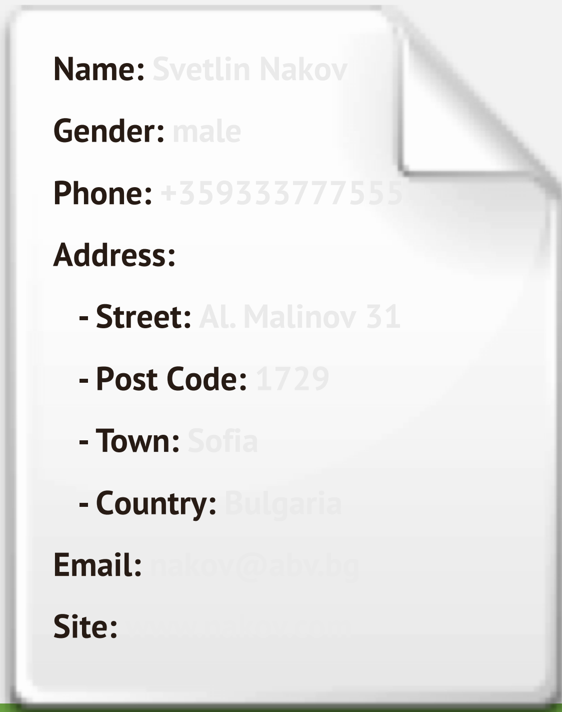
*
1

Town	Sofia

*
1

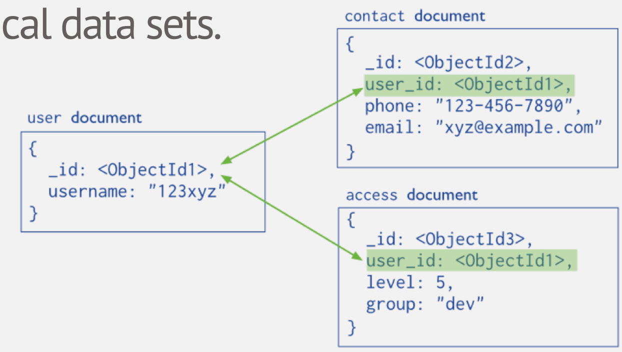
Country	Bulgaria

Document Model



Document oriented database – Normalized data model

- When to use:
  - When embedding would result in duplication of data but would not provide sufficient read performance advantages to outweigh the implications of the duplication.
  - To represent more complex many-to-many relationships.
  - To model large hierarchical data sets.
  - Multiple queries!



Redis

What is Redis?

- Redis is
  - Ultra-fast in-memory key-value data store
  - Powerful data structures server
  - Open-source software: http://redis.io
- Redis stores data structures:
  - Strings
  - Lists
  - Hash tables
  - Sets / sorted sets

Hosted Redis Providers

- Redis Cloud
  - Fully managed Redis instance in the cloud
  - Highly scalable, highly available
  - Free 1 GB instance, stored in the Amazon cloud
  - Supports data persistence and replication
  - http://redis-cloud.com
- Redis To Go
  - 5 MB free non-persistent Redis instance
  - http://redistogo.com

CouchDB

What is CouchDB?

- Apache CouchDB
  - Open-source NoSQL database
  - Document-based: stored JSON documents
  - HTTP-based API
  - Query, combine, and transform documents with JavaScript
  - On-the-fly document transformation
  - Real-time change notifications
  - Highly available and partition tolerant

Hosted CouchDB Providers

- Cloudant
  - Managed CouchDB instances in the cloud
  - Free $5 account – unclear what this means
  - https://cloudant.com
  - Has nice web-based administration UI

mongoDB

"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

Example: 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_00e8da9b	Type	Audio Album
sku_00e8da9b	Title	A Love Supreme
sku_00e8da9b	…	…
sku_00e8da9b	Artist	John Coltrane
sku_00e8da9b	Genre	Jazz
sku_00e8da9b	Genre	General

MongoDB Solution

- A “collection” can contain heterogeneous “documents”, e.g. for an audio album we could store as

```
{ 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" ]}
}
```


Hosted MongoDB Providers

- MongoLab
  - Free 0.5 GB instance
  - https://mongolab.com
- MongoHQ
  - Free 0.5 GB instance (sandbox)
  - https://www.mongohq.com
- MongoOd
  - Free 100 MB instance
  - https://www.mongood.com

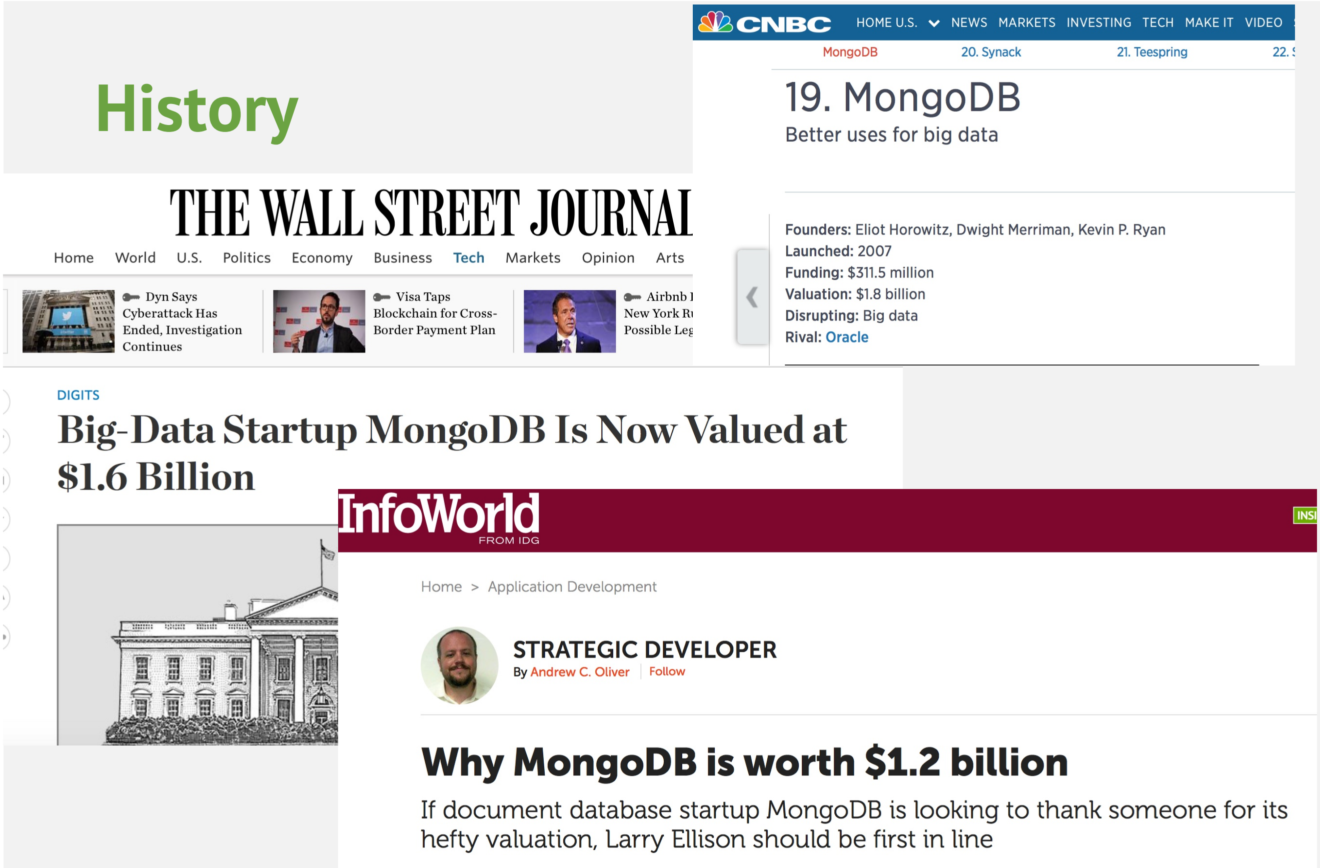
History

- mongoDB = “Hu**mongo**us DB”
  - Open-source
  - Document-based
  - “High performance, high availability”
  - Automatic scaling
  - C-P on CAP

History

- 2007 - First developed (by 10gen)
- 2009 - Became Open Source
- 2010 - Considered production ready (v 1.4 >)
- 2013 - MongoDB closes $150 Million in Funding
- 2015 - version 3 released (v 3.0.7)
- 2016 – Latest stable version (v. 3.2.10)
- Today- More than $231 million in total investment since 2007

History



Design Goals

- Scale horizontally over commodity systems
- Incorporate what works for RDBMSs
  - Rich data models, ad-hoc queries, full indexes
- Move away from what doesn't scale easily
  - Multi-row transactions, complex joins
- Use idomatic development APIs
- Match agile development and deployment workflows

To scale horizontally (or scale out/in) means to add more nodes to (or remove nodes from) a system, such as adding a new computer to a distributed software application. An example might involve scaling out from one Web server system to three.

Key Features

- Data stored as documents (JSON)
  - Dynamic-schema
- Full CRUD support (Create, Read, Update, Delete)
  - Ad-hoc queries: Equality, RegEx, Ranges, Geospatial
  - Atomic in-place updates
- Full secondary indexes
  - Unique, sparse, TTL
- Replication – redundancy, failover
- Sharding – partitioning for read/write scalability

Key Features

- All indexes in MongoDB are B-Tree indexes
- Index Types:
  - Single field index
  - Compound Index: more than one field in the collection
  - Multikey index: index on array fields
  - Geospatial index and queries.
  - Text index: Index
  - TTL index: (Time to live) index will contain entities for a limited time.
  - Unique index: the entry in the field has to b unique.
  - Sparse index: stores an index entry only for entities with the given field.

MongoDB Drivers and Shell

Drivers

Drivers for most popular programming languages and frameworks

Java .NET php Ruby

C++ JavaScript C Perl Scala

Python node JS ERLANG Haskell

Shell

Command-line shell for interacting directly with database

```
> db.collection.insert({product:"MongoDB",
type:"Document Database"})
>
> db.collection.findOne()
{
        "_id"       : ObjectId("5106c1c2fc629bfe52792e86"),
        "product"   : "MongoDB"
        "type"      : "Document Database"
}
```

Getting Started with Mongo

Installation

- Install Mongo from: http://www.mongodb.org/downloads
  - Extract the files
  - Create a data directory for Mongo to use
- Open your mongodb/bin directory and run the binary file (name depends on the architecture) to start the database server.
- To establish a connection to the server, open another command prompt window and go to the same directory, entering in mongo.exe or mongo for macs and Linuxes.
- This engages the mongodb shell—it's that easy!

MongoDB Design Model

Database		Database
Table	→	Collection
Row		Document

Mongo Data Model

- Document-Based (max 16 MB)
- Documents are in BSON format, consisting of field-value pairs
- Each document stored in a collection
- Collections
  - Have index set in common
  - Like tables of relational db's.
  - Documents do not have to have uniform structure

JSON

- "JavaScript Object Notation"
- Easy for humans to write/read, easy for computers to parse/generate
- Objects can be nested
- Built on
  - name/value pairs
  - Ordered list of values

BSON

- "Binary JSON"
- Binary-encoded serialization of JSON-like docs
- Also allows "referencing"
- Embedded structure reduces need for joins
- Goals
  - Lightweight
  - Traversable
  - Efficient (decoding and encoding)

BSON Example

```
{
"_id" : "37010",
"city" :     "ADAMS",
"pop" :      2660,
"state" :    "TN",
"councilman" : {
                 name: "John Smith",
                 address: "13 Scenic Way"
             }
}
```

BSON Types

Type	Number
Double	1
String	2
Object	3
Array	4
Binary data	5
Object id	7
Boolean	8
Date	9
Null	10
Regular Expression	11
JavaScript	13
Symbol	14
JavaScript (with scope)	15
32-bit integer	16
Timestamp	17
64-bit integer	18
Min key	255
Max key	127

The number can be used with the $type operator to query by type!

http://docs.mongodb.org/manual/reference/bson-types/

The _id Field

- By default, each document contains an _id field. This field has a number of special characteristics:
  - Value serves as primary key for collection.
  - Value is unique, immutable, and may be any non-array type.
  - Default data type is `ObjectId`, which is "small, likely unique, fast to generate, and ordered."
  - Sorting on an `ObjectId` value is roughly equivalent to sorting on creation time.

MongoDB vs. Relational Databases

RDBMS		MongoDB
Database	➜	Database
Table	➜	Collection
Row	➜	Document
Index	➜	Index
Join	➜	Embedded Document
Foreign Key	➜	Reference

mongoDB vs. SQL

MongoDB	SQL
Document	Tuple
Collection	Table/View
PK: _id Field	PK: Any Attribute(s)
Uniformity not Required	Uniform Relation Schema
Index	Index
Embedded Structure	Joins
Shard	Partition

Document Oriented, Dynamic Schema

Relational

Person:

Pers_ID	Surname	First_Name	City
0	Miller	Paul	London
1	Ortega	Alvaro	Valencia
2	Huber	Urs	Zurich
3	Blanc	Gaston	Paris
4	Bertolini	Fabrizio	Rom

no relation

Car:

Car_ID	Model	Year	Value	Pers_ID
101	Bentley	1973	100000	0
102	Rolls Royce	1965	330000	0
103	Peugeot	1993	500	3
104	Ferrari	2005	150000	4
105	Renault	1998	2000	3
106	Renault	2001	7000	3
107	Smart	1999	2000	2

MongoDB

```
{
  first_name: ‘Paul’,
  surname: ‘Miller’
  city: ‘London’,
  location: [45.123,47.232],
  cars: [
    { model: ‘Bentley’,
      year: 1973,
      value: 100000, … },
    { model: ‘Rolls Royce’,
      year: 1965,
      value: 330000, … }
  ]
}
```

MongoDB Marketing Spiel

- MongoDB (from "humongous") is a scalable, high-performance, open source, document-oriented database.
  - Fast querying & In-place updates
  - Full Secondary Index Support
  - Replication & High Availability
  - Auto-Sharding
- Currently used in a number of different applications
  - Craigslist, ebay, New York Times, Shutterfly, Chicago Tribune, Github, Disney…

CRUD:

Create, Read, Update, Delete

CRUD: Using the Shell

- To check which db you're using → db
- Show all databases → show dbs
- Switch db's/make a new one → use <name>
- See what collections exist → show collections

- Note: db's are not actually created until you insert data!

CRUD: Using the Shell (cont.)

- To insert documents into a collection/make a new collection:

- db.<collection>.insert(<document>)
- <=>
- INSERT INTO <table>
- VALUES(<attributevalues>);

CRUD: Inserting Data

- Insert one document
- db.<collection>.insert({<field>:<value>})
- Inserting a document with a field name new to the collection is inherently supported by the BSON model.
- To insert multiple documents, use an array.

CRUD: Querying

- Done on collections.
- Get all docs: db.<collection>.find()
  - Returns a cursor, which is iterated over shell to display first 20 results.
  - Add $limit(<number>) to limit results
  - SELECT * FROM <table>;
- Get one doc: db.<collection>.findOne()

CRUD: Querying

To match a specific value:

```
db.<collection>.find({<field>:<value>})
"AND"
db.<collection>.find({<field1>:<value1>, <field2>:<value2>
})
```

```
SELECT *
FROM <table>
WHERE <field1> = <value1> AND <field2> = <value2>;
```

CRUD: Querying

```
OR
db.<collection>.find({ $or: [
<field>:<value1>
<field>:<value2>        ]
})
```

```
SELECT *
FROM <table>
WHERE <field> = <value1> OR <field> = <value2>;
```

Checking for multiple values of same field

```
db.<collection>.find({<field>: {$in [<value>, <value>]}})
```


CRUD: Querying

Excluding document fields

```
db.<collection>.find({<field1>:<value>}, {<field2>: 0})
```

```
SELECT field1
FROM <table>;
```

Including document fields

```
db.<collection>.find({<field>:<value>}, {<field2>: 1})
```

Find documents with or w/o field

```
db.<collection>.find({<field>: { $exists: true}})
```

CRUD: Updating

```
db.<collection>.update(
{<field1>:<value1>},      //all docs in which field = value
{$set: {<field2>:<value2>}},         //set field to value
{multi:true} )      //update multiple docs
```

bulk.find.upsert(): if true, creates a new doc when none matches search criteria.

```
UPDATE <table>
SET <field2> = <value2>
WHERE <field1> = <value1>;
```


CRUD: Updating

To remove a field

```
db.<collection>.update({<field>:<value>},
        { $unset: { <field>: 1}})
```

Replace all field-value pairs

```
db.<collection>.update({<field>:<value>},
        { <field>:<value>, <field>:<value>})
```

*NOTE: This overwrites ALL the contents of a document, even removing fields.

CRUD: Removal

Remove all records where field = value

```
db.<collection>.remove({<field>:<value>})
```

```
DELETE FROM <table>
WHERE <field> = <value>;
```

As above, but only remove first document

```
db.<collection>.remove({<field>:<value>}, true)
```


CRUD: Isolation

- By default, all writes are atomic only on the level of a single document.
- This means that, by default, all writes can be interleaved with other operations.
- You can isolate writes on an unsharded collection by adding $isolated:1 in the query area:
  - db.<collection>.remove({<field>:<value>, $isolated: 1})

MongoDB Example II

```
db.users.insertMany(
  [
    {
      _id: 1,
      name: "sue",
      age: 19,
      type: 1,
      status: "P",
      favorites: { artist: "Picasso", food: "pizza" },
      finished: [ 17, 3 ],
      badges: [ "blue", "black" ],
      points: [
        { points: 85, bonus: 20 },
        { points: 85, bonus: 10 }
      ]
    },
    {
      _id: 2,
      name: "bob",
      age: 42,
      type: 1,
      status: "A",
      favorites: { artist: "Miro", food: "meringue" },
      finished: [ 11, 25 ],
      badges: [ "green" ],
      points: [
        { points: 85, bonus: 20 },
        { points: 64, bonus: 12 }
      ]
    },
    {
      _id: 3,
      name: "ahn",
      age: 22,
      type: 2,
      status: "A",
      favorites: { artist: "Cassatt", food: "cake" },
      finished: [ 6 ],
      badges: [ "blue", "red" ],
      points: [
        { points: 81, bonus: 8 },
        { points: 55, bonus: 20 }
      ]
    },
    {
      _id: 4,
      name: "xi",
      age: 34,
      type: 2,
      status: "D",
      favorites: { artist: "Chagall", food: "chocolate" },
      finished: [ 5, 11 ],
      badges: [ "red", "black" ],
      points: [
        { points: 53, bonus: 15 },
        { points: 51, bonus: 15 }
      ]
    },
)
```

Insert

- db.collection.insertOne()
- db.collection.insertMany()
- db.collection.insert()
- Example

```
db.users.insertMany(
  [
    { name: "bob", age: 42, status: "A", },
    { name: "ahn", age: 22, status: "A", },
    { name: "xi", age: 34, status: "D", }
  ]
)
```


Update

- db.collection.updateOne()
- db.collection.updateMany()
- db.collection.replaceOne()
- db.collection.update()
- Example

```
db.users.updateOne(
  { "favorites.artist": "Picasso" },
  {
    $set: { "favorites.food": "pie", type: 3 },
    $currentDate: { lastModified: true }
  }
)
```

Return All Fields in Matching Documents

- Retrieve from the users collection all documents where the status equals "A"
  - db.users.find({ status: "A" })

Return the Specified Fields and the _id Field Only

- A projection can explicitly include several fields
  - Return all documents that match the query
    - db.users.find({ status: "A" }, { name: 1, status: 1 })

- This will result in the following:

  { "_id" : 2, "name" : "bob", "status" : "A" }
  { "_id" : 3, "name" : "ahn", "status" : "A" }

Return the Specified Fields

- Remove the _id field from the results by specifying its exclusion in the projection
  - db.users.find({ status: "A" }, { name: 1, status: 1, _id: 0 })
- This will result in the following:

```
{ "name" : "bob", "status" : "A" }
{ "name" : "ahn", "status" : "A" }
{ "name" : "abc", "status" : "A" }
```


Return All But the Excluded Field

- Use a projection to exclude specific fields
  - db.users.find({ status: "A" }, { favorites: 0, points: 0 })
- Returns

```
{
  "_id" : 2,
  "name" : "bob",
  "age" : 42,
  "type" : 1,
  "status" : "A",
  "finished" : [ 11, 25 ],
  "badges" : [ "green" ]
}
…
```

Return Specific Fields in Embedded Documents

- Use the dot notation to return specific fields in an embedded document
  - db.users.find({ status: "A" }, { name: 1, status: 1, "favorites.food": 1 })
- Returns the following fields inside the favorites document

  { "_id" : 2, "name" : "bob", "status" : "A", "favorites" : { "food" : "meringue" } }
  { "_id" : 3, "name" : "ahn", "status" : "A", "favorites" : { "food" : "cake" } }

Suppress Specific Fields in Embedded Documents

- Exclude the food field inside the favorites document

```
db.users.find(
  { status: "A" },
  { "favorites.food": 0 }
)
```

- Returns

```
{
  "_id" : 2,
  "name" : "bob",
  "age" : 42,
  "type" : 1,
  "status" : "A",
  "favorites" : { "artist" : "Miro" },
  "finished" : [ 11, 25 ],
  "badges" : [ "green" ],
  "points" : [ { "points" : 85, "bonus" : 20 }, { "points" : 64, "bonus" : 12 } ]
}
...
```

SQL Schema Statements	MongoDB Schema Statements
`CREATE TABLE users ( id MEDIUMINT NOT NULL AUTO_INCREMENT, user_id Varchar(30), age Number, status char(1), PRIMARY KEY (id) )`	Implicitly created on first insert() operation. The primary key _id is automatically added if _id field is not specified. `db.users.insert( { user_id: "abc123", age: 55, status: "A" } )` However, you can also explicitly create a collection: `db.createCollection("users")`
`ALTER TABLE users ADD join_date DATETIME`	Collections do not describe or enforce the structure of its documents; i.e. there is no structural alteration at the collection level. However, at the document level, update() operations can add fields to existing documents using the $set operator. `db.users.update( { }, { $set: { join_date: new Date() } }, { multi: true } )`

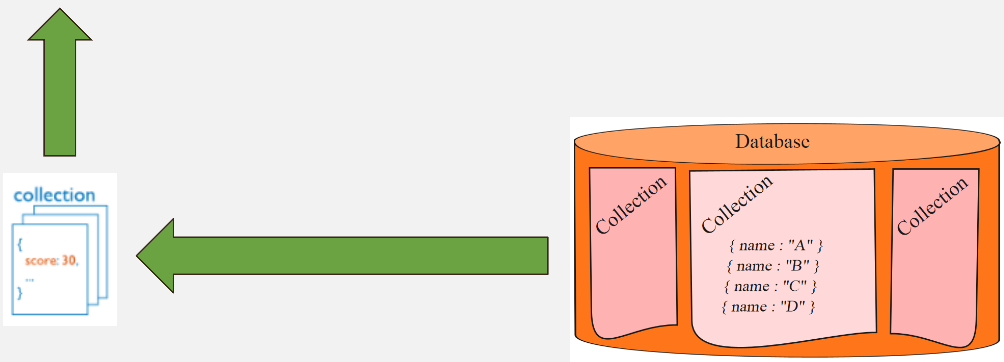
`ALTER TABLE users DROP COLUMN join_date`	Collections do not describe or enforce the structure of its documents; i.e. there is no structural alteration at the collection level. However, at the document level, update() operations can remove fields from documents using the $unset operator. `db.users.update( { }, { $unset: { join_date: "" } }, { multi: true } )`
`CREATE INDEX idx_user_id_asc ON users(user_id)`	`db.users.createIndex( { user_id: 1 } )`
`CREATE INDEX idx_user_id_asc_age_desc ON users(user_id, age DESC)`	`db.users.createIndex( { user_id: 1, age: -1 } )`
`DROP TABLE users`	`db.users.drop()`

Index in MongoDB

Before Index

- What does database normally do when we query?
  - MongoDB must scan every document.
  - Inefficient because process large volume of data

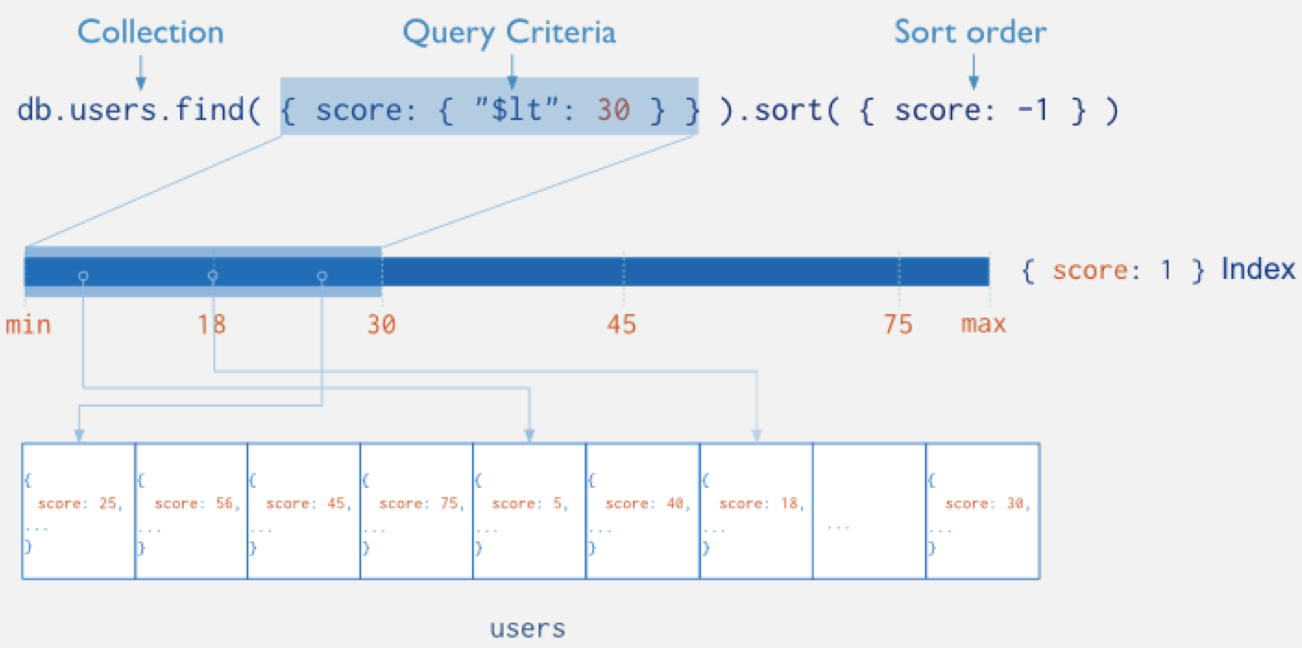
db.users.find({ score: { "$lt" : 30} })



Index in MongoDB: Operations

- Creation index
  - db.users.ensureIndex({ score: 1 })
  - db.people.createIndex({ zipcode: 1}, {background: **true**})
- Show existing indexes
  - db.users.getIndexes()
- Drop index
  - db.users.dropIndex({score: 1})
- Explain—Explain
  - db.users.find().explain()
  - Returns a document that describes the process and indexes
- Hint
  - db.users.find().hint({score: 1})
  - Overide MongoDB's default index selection

Index in MongoDB: Operations



Index in MongoDB

- Types
  - **Single Field Indexes**
  - Compound Field Indexes
  - Multikey Indexes
- Single Field Indexes
  - db.users.ensureIndex({ score: 1 })

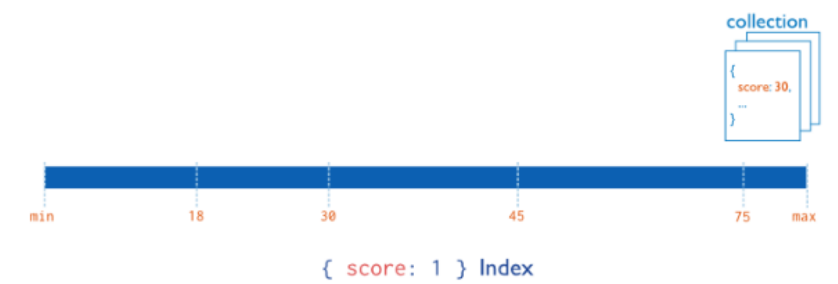


Diagram of an index on the score field (ascending).

Index in MongoDB

- Types
  - Single Field Indexes
  - **Compound Field Indexes**
  - Multikey Indexes
- Compound Field Indexes
  - db.users.ensureIndex({ userid:1, score:-1 })

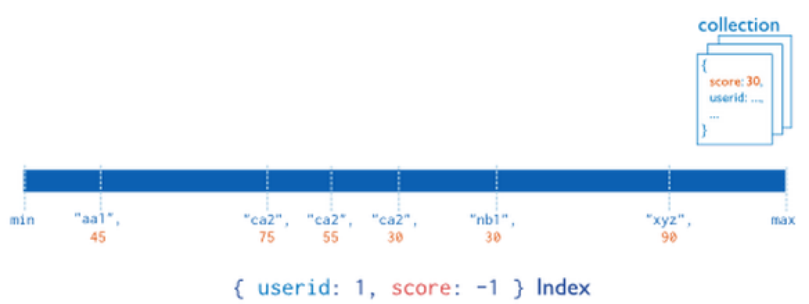


Diagram of a compound index on the userid field (ascending) and the score field (descending). The index sorts first by the userid field and then by the score field.

Index in MongoDB

- Types
  - Single Field Indexes
  - Compound Field Indexes
  - Multikey Indexes
- Multikey Indexes
  - db.users.ensureIndex({ addr.zip:1})

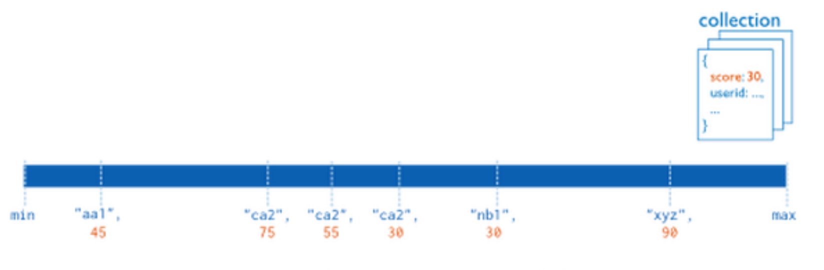


Diagram of a compound index on the userid field (ascending) and the score field (descending). The index sorts first by the userid field and then by the score field.

Other Indexes in MongoDB

- Geospatial Index
- Text Indexes
- Hashed Indexes

Mongo Example I

Documents

```
> var new_entry = {
  firstname: “John”,
  lastname: “Smith”,
  age: 25,
  address: {
    street: “21 2nd Street”,
    city: “New York”,
    state: “NY”,
    zipcode: 10021
  }
}
> db.addressBook.save(new_entry)
```

Querying

```
> db.addressBook.find()
{
  _id: ObjectId("4c4ba5c0672c685e5e8aabf3"),
  firstname: "John",
  lastname: "Smith",
  age: 25,
  address: {
    street: "21 2nd Street", city: "New York",
    state: "NY", zipcode: 10021
  }
}
// _id is unique but can be anything you like
```


Indexes

```
// create an ascending index on "state"
> db.addressBook.ensureIndex({state:1})

> db.addressBook.find({state:"NY"})
{
  _id: ObjectId("4c4ba5c0672c685e5e8aabf3"),
  firstname: "John",
  …
}

> db.addressBook.find({state:"NY", zip: 10021})
```

Queries

```
// Query Operators:
// $all, $exists, $mod, $ne, $in, $nin, $nor, $or,
// $size, $type, $lt, $lte, $gt, $gte

// find contacts with any age
> db.addressBook.find({age: {$exists: true}})

// find entries matching a regular expression
> db.addressBook.find( {lastname: /^smi*/i } )

// count entries with “John”
> db.addressBook.find( {firstname: ‘John’} ).count()
```


Updates

```
// Update operators
// $set, $unset, $inc, $push, $pushAll, $pull,
// $pullAll, $bit

> var new_phonenumber = {
  type: “mobile”,
  number: “646-555-4567”
}

> db.addressBook.update({ _id: “...” }, {
  $push: {phonenumbers: new_phonenumber}
});
```

Nested Documents

```
{
  _id: ObjectId("4c4ba5c0672c685e5e8aabf3"),
  firstname: “John”, lastname: “Smith”,
  age: 25,
  address: {
    street: “21 2nd Street”, city: “New York”,
    state: “NY”, zipcode: 10021
  }
  phonenumbers : [ {
    type: “mobile”, number: “646-555-4567”
  } ]
}
```


Secondary Indexes

```
// Index nested documents
> db.addressBook.ensureIndex({“phonenumbers.type”:1})

// Geospatial indexes, 2d or 2dsphere
> db.addressBook.ensureIndex({location: “2d”})
> db.addressBook.find({location: {$near: [22,42]}})

// Unique and Sparse indexes
> db.addressBook.ensureIndex({field:1}, {unique:true})
> db.addressBook.ensureIndex({field:1}, {sparse:true})
```

Additional Features

- Geospatial queries
  - Simple 2D plane
  - Or accounting for the surface of the earth (ellipsoid)
- Full Text Search
- Aggregation Framework
  - Similar to SQL GROUP BY operator
- Javascript MapReduce
  - Complex aggregation tasks

Mongo Example II

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

- db.posts.find()
  - returns entire collection in posts
- 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" ]
  }
```

Specifying Which Keys to Return

- db.mydoc.find({}, { “name” , { “contribs” })

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

- db.mydoc.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}, { “name” : “John” }]})

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 (order is now important):
  - db.people.find({ “name” : { “first” : “John” , “last” : “Smith” }})

Limits, Skips, Sort, Count

- db.posts.find().limit(3)
  - Limits the number of results to 3
- db.posts.find().skip(3)
  - Skips the first three results and returns the rest
- db.posts.find().sort({ "author" :1, "title" :-1})
  - Sorts by author ascending (1) and title descending (-1)
- db.people.find(…).count()
  - Counts the number of documents in the people collection matching the find(…)

Revisiting 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} ]
                         }
> db.people.insert(mydoc)
```

Also assume…

```
award1=
 {_id: “NMS001”,
  title:  “National Medal of Science” ,
  by: “National Science Foundation”}
award2=
 {_id: “TA99”,
  title:  “Turing Award”,
  by: “ACM” }
db.awards.insert(award1)
db.awards.insert(award2)
```


“SemiJoins”

- Suppose you want to print people who have won Turing Awards
  - Problem: object id of Turing Award is in collection “awards” ,collection “people” references it.

```
turing= db.awards.findOne({title: “Turing Award”})
db.people.find({"awards.award_id": turing["_id"]})
```

Aggregation

- A framework to provide "group-by" and aggregate functionality without the overhead of map-reduce.
- Conceptually, documents from a collection pass through an aggregation pipeline, which transforms the objects as they pass through (similar to UNIX pipe "|")
- Operators include: $project, $match, $limit, $skip, $sort, $unwind, $group

Unwind

- db.article.aggregate({ $project : { author : 1, tags : 1 }}, { $unwind : "$tags" })

```
{ "result" : [ { "_id" : ObjectId("4e6e4ef557b77501a49233f6"),
                   "author" : "bob",
                   "tags" : "fun" },
                 { "_id" : ObjectId("4e6e4ef557b77501a49233f6"),
                   "author" : "bob",
                   "tags" : "good" },
                 { "_id" : ObjectId("4e6e4ef557b77501a49233f6"),
                   "author" : "bob",
                   "tags" : "fun" } ],
   "OK" : 1 }
```

$group

- Every group expression must specify an _id field.
- For example, suppose you wanted to print the number of people born in each year

```
> db.people.aggregate( { $group :
        { _id : "$birthyear", birthsPerYear : { $sum : 1}} )
{ "result" : [ { "_id" : 1924, "count" : 1 } ], "ok" : 1 }
```


MongoDB Development

Open Source

- MongoDB source code is on Github
  – https://github.com/mongodb/mongo
- Issue tracking for MongoDB and drivers
  – http://jira.mongodb.org

Summary 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
  – Joins are done via a query language
- The power of the solution lies in the distributed, parallel nature of query processing
  – Replication and sharding