MongoDB Developer Training

MongoDB Developer Training

Release 2.6

MongoDB, Inc.

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Contents

1 Introduction

1.1 Warm Up

Introductions

- Who am I?
- My role at MongoDB
- My background and prior experience

Notes:

Getting to Know You

- Who are you?
- What role do you play in your organization?
- What is your background?
- Do you have prior experience with MongoDB?

Notes:

MongoDB Experience

- Who has never used MongoDB?
- Who has some experience?
- Who has worked with production MongoDB deployments?
- Who is more of a developer?
- Who is more of operations person?

Notes:

10gen

- MongoDB was initially created in 2008 as part of a hosted application stack.
- The company was originally called 10gen.
- As part of their overarching plan to create the 10gen platform, the company built a database.
- Suddenly everybody said: “I like that! Give me that database!”

Notes:

Origin of MongoDB

- 10gen became a database company.
- In 2013, the company rebranded as MongoDB, Inc.
- The founders have other startups to their credit: DoubleClick, ShopWiki, Gilt.
- The motivation for the database came from observing the following pattern with application development.
  - The user base grows.
  - The associated body of data grows.
  - Eventually the application outgrows the database.
  - Meeting performance requirements becomes difficult.

Notes:

1.2 MongoDB Overview

Learning Objectives

Upon completing this module students should understand:

- MongoDB vs. relational databases and key/value stores
- Vertical vs. horizontal scaling
- The role of MongoDB in the development stack
- The structure of documents in MongoDB
- Array fields
- Embedded documents
- Fundamentals of BSON

Notes:

MongoDB is a Document Database

Documents are associative arrays like:

- Python dictionaries
- Ruby hashes
- PHP arrays
- JSON objects

Notes:

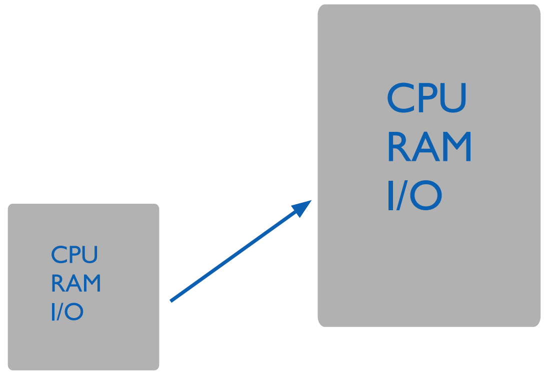
An Example MongoDB Document

A MongoDB document expressed using JSON syntax.

```
{
    "a" : 3,
    "b" : [3, 2, 7],
    "c" : {
        "d" : 4 ,
        "e" : "asdf",
        "f" : true,
        "h" : ISODate("2014-10-23T01:19:40.732Z")
    }
}
```

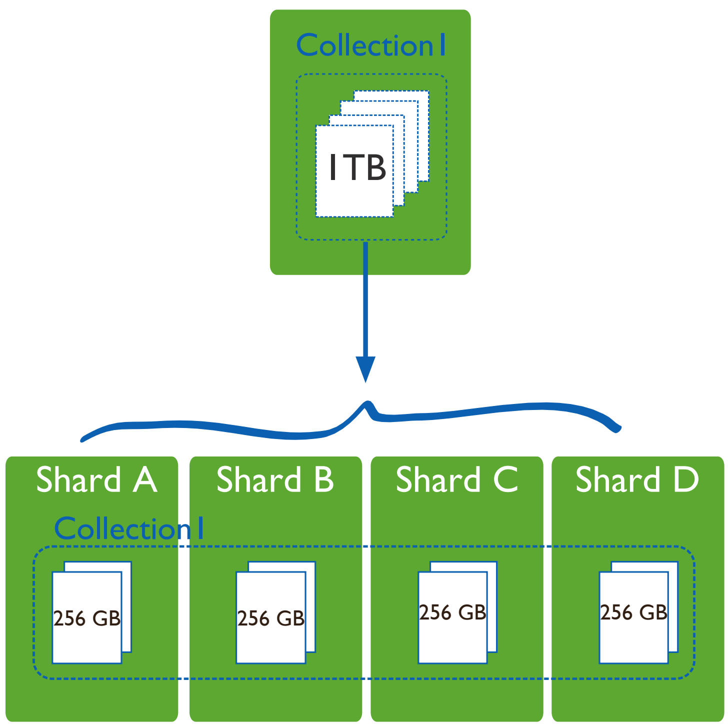
Notes:

Vertical Scaling



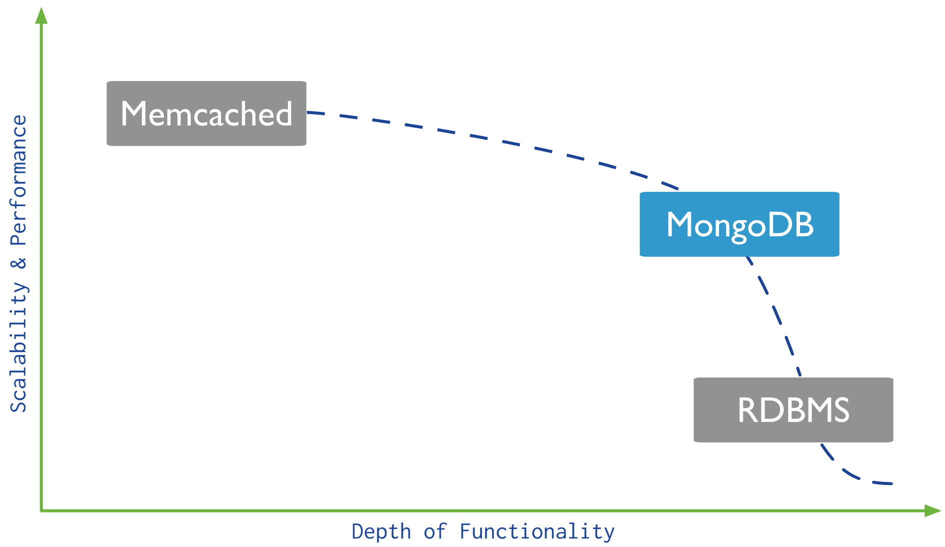
Notes:

Scaling with MongoDB



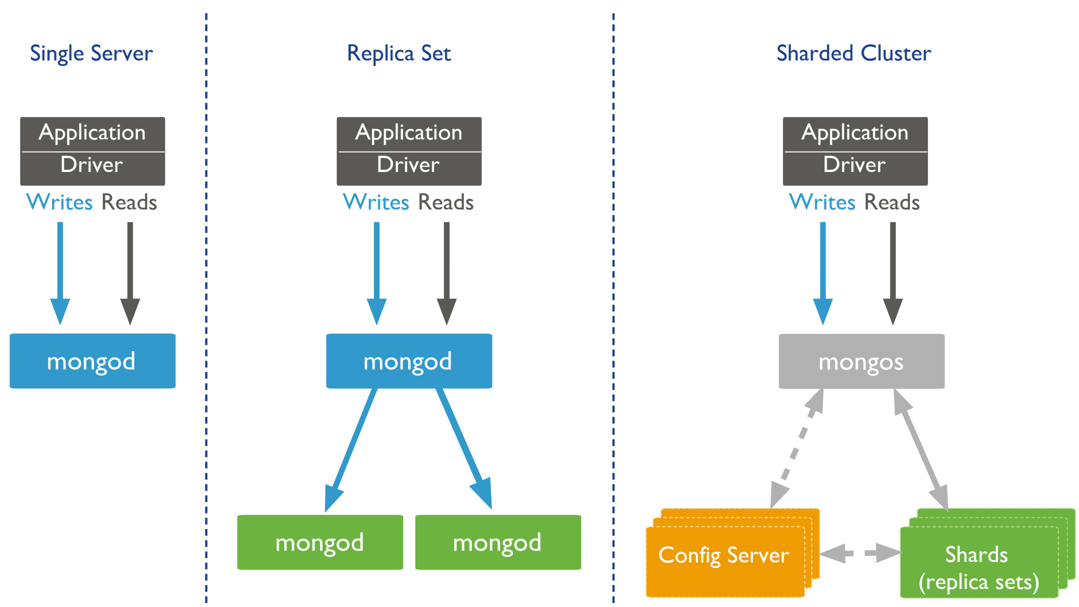
Notes:

Database Landscape



Notes:

MongoDB Deployment Models



Notes:

1.3 MongoDB Stores Documents

Learning Objectives

Upon completing this module, students should understand:

- JSON
- BSON basics
- That documents are organized into collections
- ObjectIds
- Padding Factor

Notes:

JSON

- JavaScript Object Notation
- Objects are associative arrays.
- They are composed of key-value pairs.

Notes:

A Simple JSON Object

```
{
    "firstname" : "Thomas",
    "lastname" : "Smith",
    "age" : 29
}
```

Notes:

JSON Keys and Values

- Keys must be strings.
- Values may be any of the following:
  - string (e.g., "Thomas")
  - number (e.g., 29, 3.7)
  - true / false
  - null
  - array (e.g., [88.5, 91.3, 67.1])
  - object
- More detail at json.org[1].

Notes:

Example Field Values

```
{
    "first key" : "value" ,
    "second key" : {
        "first embedded key" : "first embedded value",
        "second embedded key" : "second embedded value"
     },
     "third key" : [
         "first array element",
         "second element",
         { "embedded key" : "embedded value" },
         [ 1, 2 ]
     ]
}
```

Notes:

[1] http://json.org/

BSON

- MongoDB stores data as Binary JSON (BSON).
- MongoDB drivers send and receive data in this format.
- They map BSON to native data structures.
- BSON provides support for all JSON data types and several others.
- BSON was designed to be lightweight, traversable and efficient.
- See bsonspec.org[2].

Notes:

BSON Hello World

```
// JSON
{ "hello" : "world" }

// BSON
"\x16\x00\x00\x00\x02hello\x00
 \x06\x00\x00\x00world\x00\x00"
```

Notes:

A More Complex BSON Example

```
// JSON
{ "BSON" : [ "awesome", 5.05, 1986 ] }

// BSON
"\x3b\x00\x00\x00\x04BSON\x00\x26\x00
 \x00\x00\x020\x00\x08\x00\x00
 \x00awesome\x00\x011\x00\x33\x33\x33\x33\x33\x33
 \x14\x40\x102\x00\xc2\x07\x00\x00
 \x00\x00"
```

Notes:

[2] http://bsonspec.org/#/specification

Documents, Collections, and Databases

- Documents are stored in collections.
- Collections are contained in a database.
- Example:
  - Database: products
  - Collections: books, movies, music
- Each database-collection combination defines a namespace.
  - products.books
  - products.movies
  - products.music

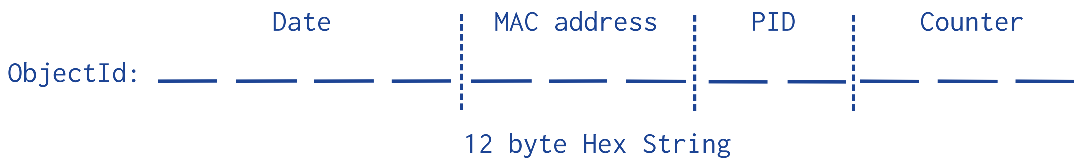
Notes:

The `_id` Field

- All documents must have an `_id` field.
- The `_id` is immutable.
- If no `_id` is specified when a document is inserted, MongoDB will add the `_id` field.
- MongoDB assigns a unique ObjectId as the value of `_id`.
- Most drivers will actually create the ObjectId if no `_id` is specified.
- The `_id` field is unique to a collection (namespace).

Notes:

ObjectIds



Notes:

Storing BSON Documents

- Each document may be a different size from the others.
- The maximum BSON document size is 16 megabytes.
- Documents are physically adjacent to each other on disk and in memory.
- If a document is updated in a way that makes it larger, MongoDB may move the document.
- This may cause fragmentation, resulting in unnecessary I/O.
- Strategies to reduce the effects of document growth:
  - Padding factor
  - `usePowerOf2Sizes`

Notes:

Padding Factor

Notes:

`usePowerOf2Sizes`

- When a document must move to a new location this leaves a fragment.
- MongoDB will attempt to fill this fragment with a new document eventually.
- As of MongoDB 2.6, collections have a setting called `usePowerOf2Sizes` enabled by default for newly created collections.
- This setting will round the size of the document up to the next power of 2.
- E.g, a document that 118 bytes will be allocated 128 bytes.
- If moved, the space can be filled with two 64-byte documents, four 32-byte documents, etc.

Notes:

1.4 Exercise: Installing MongoDB

Learning Objectives

Upon completing this exercise students should understand:

- How MongoDB is distributed
- How to install MongoDB
- Configuration steps for setting up a simple MongoDB deployment
- How to run MongoDB
- How to run the Mongo shell

Notes:

Production Releases

64-bit production releases of MongoDB are available for the following platforms.

- Windows
- OSX
- Linux
- Solaris

Notes:

Installing MongoDB

- Visit http://www.mongodb.org/downloads
- Download and install the appropriate package for your machine.
- Even-numbered builds are production releases, e.g., 2.4.x, 2.6.x.
- Odd-numbers indicate development releases, e.g., 2.5.x, 2.7.x.
- 32-bit versions should NOT be used in production (limited to 2GB of data). They are acceptable for training classes.

Notes:

Setup

```
PATH=$PATH:path_to_mongodb/bin

sudo mkdir -p /data/db

sudo chmod -R 777 /data/db
```

Notes:

Launch a `mongod`

```
/<path_to_mongodb>/bin/mongod --help
```

```
/<path_to_mongodb>/bin/mongod
```

Notes:

Import Exercise Data

```
cd usb_drive
```

```
unzip sampledata.zip
```

```
cd sampledata
```

```
mongoimport -d sample -c tweets twitter.json
```

```
mongoimport -d sample -c zips zips.json
```

```
cd dump
```

```
mongorestore -d sample training
```

```
mongorestore -d sample digg
```

Notes:

Launch a Mongo Shell

Open another command shell. Then type the following to start the Mongo shell.

```
mongo
```

Display available commands.

```
help
```

Notes:

Explore Databases

Display available databases.

```
show dbs
```

To use a particular database we can type the following.

```
use <database_name>

db
```

Notes:

Exploring Collections

```
show collections

db.collection.help()

db.collection.find()
```

Notes:

Admin Commands

- There are also a number of admin commands at our disposal.
- The following will shut down the mongod we are connected to through the Mongo shell.
- You can also just kill with Ctrl-C in the shell window from which you launched the mongod.

  ```
  db.adminCommand( { shutdown : 1 } )
  ```

- Confirm that the mongod process has indeed stopped.
- Once you have, please restart it.

Notes:

The MongoDB Data Directory

```
ls /data/db
```

- The mongod.lock file
  - This prevents multiple mongods from using the same data directory simultaneously.
  - Each MongoDB database directory has one .lock.
  - The lock file contains the process id of the mongod that is using the directory.
- Data files
  - The names of the files correspond to available databases.
  - A single database may have multiple files.

Notes:

2 CRUD

2.1 Creating and Deleting Documents

Learning Objectives

Upon completing this module students should understand:

- How to insert documents into MongoDB collections.
- `_id` fields:
- How to remove documents from a collection
- How to remove a collection from a database
- How to remove a database from a MongoDB deployment

Notes:

Creating New Documents

- Create documents using `insert()`.
- For example:

```
db.collection.insert( { "name" : "susan" } )
```

Notes:

Exercise: Inserting a Document

Experiment with the following commands.

```
use sample

db.hellos.insert( { a : "hello, world!" } )

db.hellos.find()
```

Notes:

Implicit `_id` Assignment

- We did not specify an `_id` in the document we inserted.
- If you do not assign one, MongoDB will create one automatically.
- The value will be of type ObjectId.

Notes:

Exercise: Assigning _ids

Experiment with the following commands.

```
db.hellos.insert( { _id : 253, a : "a string" } )

db.hellos.find()
```

Notes:

Inserts will fail if...

- There is already a document in the collection with that `_id`.
- You try to assign an array to the `_id`.
- The argument is not a well-formed document.

Notes:

Exercise: Inserts will fail if...

```
// fails because _id can't have an array value
db.hellos.insert( { _id : [ 1, 2, 3 ] } )

// succeeds
db.hellos.insert( { _id : 3 } )

// fails because of duplicate id
db.hellos.insert( { _id : 3 } )

// malformed document
db.hellos.insert( { "hello" } )
```

Notes:

Bulk Inserts

- MongoDB 2.6 introduced bulk inserts.
- You may bulk insert using an array of documents.
- The API has two core concepts:
  - Ordered bulk operations
  - Unordered bulk operations
- The main difference is in the way the operations are executed in bulk.

Notes:

Ordered Bulk Insert

- For ordered inserts MongoDB will stop processing inserts upon encountering an error.
- Meaning that only inserts occurring before an error will complete.
- The default setting for `db.collection.insert` is an ordered insert.
- See the next exercise for an example.

Notes:

Exercise: Ordered Bulk Insert

Experiment with the following bulk insert.

```
db.things.insert( [ { _id : 19, type : "atom", symbol : "K" },
                    { _id : 20, type : "car", color : "red" },
                    { _id : 20, type : "planet", name : "Saturn" },
                    { type : "office",
                      street : "229 West 43rd Street, 5th Floor",
                      city : "New York",
                      state : "NY" } ] )

db.things.find()
```

Notes:

Unordered Bulk Insert

- Pass `{ ordered : false }` to insert to perform unordered inserts.
- If any given insert fails, MongoDB will still attempt the others.
- The inserts may be executed in a different order from the way in which you specified them.
- The next exercise is very similar to the previous one.
- However, we are using `{ ordered : false }`
- One insert will fail, but all the rest will succeed.

Notes:

Exercise: Unordered Bulk Insert

Experiment with the following bulk insert.

```
db.otherThings.insert( [ { _id : 19, type : "atom", symbol : "K" },
                         { _id : 20, type : "car", color : "red" },
                         { _id : 20, type : "planet", name : "Saturn" },
                         { type : "office",
                           street : "229 West 43rd Street, 5th Floor",
                           city : "New York",
                           state : "NY" } ],
                       { ordered : false } )
db.otherThings.find()
```

Notes:

The Shell is a JavaScript Interpreter

- Sometimes it is convenient to create test data using a little JavaScript.
- The mongo shell is a fully-functional JavaScript interpreter. You may:
  - Define functions
  - Use loops
  - Assign variables
  - Perform inserts

Notes:

Exercise: Creating Data in the Shell

Experiment with the following commands.

```
for (i=1; i<=10000; i++) {
    db.stuff.insert( { "a" : i } )
}

db.stuff.find()
```

Notes:

Deleting Documents

You may delete documents from a MongoDB deployment in several ways.

- Use `remove()` to delete documents matching a specific set of conditions.
- Drop an entire collection.
- Drop a database.

Notes:

Using `remove()`

- Remove documents from a collection using `remove()`.
- This command has one required parameter, a query document.
- All documents in the collection matching the query document will be removed.
- Pass an empty document to remove all documents.
- Prior to MongoDB 2.6 calling `remove()` with no parameters would remove all documents.
- Limit `remove()` to one document using `justOne`.

Notes:

Exercise: Removing Documents

Experiment with removing documents. Do a `find()` after each `remove()` command below.

```
for (i=1; i<=20; i++) { db.testcol.insert( { _id : i, a : i } ) }

db.testcol.remove( { a : 1 } )  // Remove the first document

// $lt is a query operator that enables us to select documents that
// are less than some value. More on operators soon.
db.testcol.remove( { a : { $lt : 5 } } )  // Remove three more

db.testcol.remove( { a : { $lt : 10 } },
                         { justOne : true } )  // Remove one more

db.testcol.remove()  // Error: requires a query document.

db.testcol.remove( { } )  // All documents removed
```

Notes:

Dropping a Collection

- You can drop an entire collection with `db.collection.drop()`
- The collection and all documents will be deleted.
- It will also remove any metadata associated with that collection.
- Indexes are one type of metadata removed.
- More on meta data later.

Notes:

Exercise: Dropping a Collection

```
db.colToBeDropped.insert( { a : 1 } )
show collections  // Shows the colToBeDropped collection

db.colToBeDropped.drop()
show collections  // collection is gone
```

Notes:

Dropping a Database

- You can drop an entire database with `db.dropDatabase()`
- This drops the database on which the method is called.
- It also deletes the associated data files from disk, freeing disk space.
- Beware that in the mongo shell, this does not change database context.

Notes:

Exercise: Dropping a Database

```
use tempDB
db.testcol1.insert( { a : 1 } )
db.testcol2.insert( { a : 1 } )

show dbs  // Here they are
show collections  // Shows the two collections

db.dropDatabase()
show collections  // No collections
show dbs  // The db is gone

use sample  // take us back to the sample db
```

Notes:

2.2 Reading Documents

Learning Objectives

Upon completing this module students should understand:

- The query-by-example paradigm of MongoDB
- How to query on array elements
- How to query embedded documents using dot notation
- How the mongo shell and drivers use cursors
- Cursor methods: `.count()`, `.sort()`, `.skip()`, `.limit()`

Notes:

The `find()` Method

- This is the fundamental method by which we read data from MongoDB.
- We have already used it in its basic form.
- `find()` returns a cursor that enables us to iterate through all documents matching a query.
- We will discuss cursors later.

Notes:

Query by Example

- To query MongoDB, specify a document containing the key / value pairs you want to match
- You need only specify values for fields you care about.
- Other fields will not be used to exclude documents.
- The result set will include all documents in a collection that match.

Notes:

Exercise: Querying by Example

Experiment with the following sequence of commands.

```
db.testcol.drop()
db.testcol.insert( [ { _id : 1, a : 5, b : 3 },
                     { _id : 3, b : 5, c : 12 },
                     { a : 7, b : 3 },
                     { c : 5, b : 7 } ] )
db.testcol.find()

db.testcol.find( { a : 5 } )

db.testcol.find( { b : 3, a : 7 } )
```

Notes:

Querying Arrays

- In MongoDB you may query array fields.
- Specify a single value you expect to find in that array in desired documents.
- Alternatively, you may specify an entire array in the query document.
- As we will see later, there are also several operators that enhance our ability to query array fields.

Notes:

Exercise: Querying Arrays

Experiment with the following sequence of commands.

```
db.testcol.drop()
db.testcol.insert( [ { a : [ 1, 2, 3 ] },
                     { a : [ 3, 4, 5 ] },
                     { a : [ 5, 6, 7 ] } ] )

 // These match documents where a contains the value specified
 db.testcol.find( { a : 3 } )
 db.testcol.find( { a : 5 } )

 // These match documents where a equals the value specified
 db.testcol.find( { a : [ 3, 5 ] } )  // no documents
 db.testcol.find( { a : [ 3, 4, 5 ] } )  // only the second document
```

Notes:

Querying with Dot Notation

- Dot notation is used to query on fields in embedded documents.
- The syntax is:

  ```
  "field1.field2" : value
  ```

- Put quotes around the field name when using dot notation.

Notes:

Exercise: Querying with Dot Notation

```
db.buildings.insert(
    [ {
          type : "house",
          location : { streetNumber : 123,
                       street : "7th Ave" } },
      {
          type : "office",
          location : { streetNumber : 234,
                       street : "7th Ave",
                       floor : 7 } },
      {
          type : "apartment",
          location : { streetNumber : 335,
                       street : "43rd Street",
                       number : 745 } } ] )

db.buildings.find( { "location.street" : "7th Ave" } ) // Two matches
```

Notes:

Exercise: Arrays and Dot Notation

Experiment with the following commands.

```
db.things.insert( [
    { type : "fruit",
      examples : [ { type : "banana", color : "yellow" },
                   { type : "apple", color : "red" },
                   { type : "mango", color : "red" } ] },
    { type : "cars",
      examples : [ { model : "Camaro", color : "red" },
                   { model : "Pinto", color : "yellow" },
                   { model : "Tacoma", color : "blue" } ] },
    { type : "planets",
      examples : [ { name : "Mars", color : "red" },
                   { name : "Venus", color : "blue" },
                   { name : "Earth", color : "blue" } ] } ] )

 db.things.find( { "examples.color" : "blue" } ) // two documents
```

Notes:

Cursors

- When you use `find()`, MongoDB returns a cursor.
- A cursor is a pointer to the result set
- You can get iterate through documents in the result using `next()`.
- By default, the mongo shell will iterate through 20 documents at a time.

Notes:

Exercise: Introducing Cursors

Experiment with the following commands.

```
db.testcol.drop()
for (i=1; i<=10000; i++) {
    db.testcol.insert( { a : Math.floor( Math.random() * 100 + 1 ),
                         b : Math.floor( Math.random() * 100 + 1 ) } )
}
db.testcol.find()

it
it
```

Notes:

Exercise: Cursor Objects in the Mongo Shell

```
// Assigns the cursor returned by find() to a variable x
var x = db.testcol.find()

// Displays the first document in the result set.
x.next()

// True because there are more documents in the result set.
x.hasNext()

// Assigns the next document in the result set to the variable y.
y = x.next()

// Return value is the value of the a field of this document.
y.a

// Displaying a cursor prints the next 20 documents in the result set.
x
```

Notes:

Cursor Methods

- `count()`: Returns the number of documents in the result set.
- `limit()`: Limits the result set to the number of documents specified.
- `skip()`: Skips the number of documents specified.

Notes:

Exercise: Using `count()`

```
db.testcol.drop()
for (i=1; i<=100; i++) { db.testcol.insert( { a : i } ) }

// all 100
db.testcol.count()

// just 41 docs
db.testcol.count( { a : { $lt : 42 } } )

// Another way of writing the same query
db.testcol.find( { a : { $lt : 42 } } ).count(  )
```

Notes:

Exercise: Using `sort()`

Experiment with the following sort commands.

```
db.testcol.drop()
for (i=1; i<=20; i++) {
    db.testcol.insert( { a : Math.floor( Math.random() * 10 + 1 ),
                         b : Math.floor( Math.random() * 10 + 1 ) } )
}

db.testcol.find()

// sort descending; use 1 for ascending
db.testcol.find().sort( { a : -1 } )

// sort by b, then a
db.testcol.find().sort( { b : 1, a : 1 } )

// $natural order is just the order on disk.
db.testcol.find().sort( { $natural : 1 } )
```

Notes:

The `skip()` Method

- Skips the specified number of documents in the result set.
- The returned cursor will begin at the first document beyond the number specified.
- Regardless of the order in which you specify `skip()` and `sort()` on a cursor, `sort()` happens first.

Notes:

The `limit()` Method

- Limits the number of documents in a result set to the first `k`.
- Specify `k` as the argument to `limit()`
- Regardless of the order in which you specify `limit()`, `skip()`, and `sort()` on a cursor, `sort()` happens first.
- Helps reduce resources consumed by queries.

Notes:

The `distinct()` Method

- Returns all values for a field found in a collection.
- Only works on one field at a time.
- Input is a string (not a document)

Notes:

Exercise: Using `distinct()`

Experiment with the following commands and note what `distinct()` returns.

```
db.testcol.drop()
db.testcol.insert( [ { a : 2 , b : 3 },
                     { a : 2 },
                     { a : "hello" },
                     { a : "hello" },
                     { a : { hello : "world" } } ] )
db.testcol.distinct( "a" )
```

Notes:

2.3 Query Operators

Learning Objectives

Upon completing this module students should understand the following types of MongoDB query operators:

- Comparison operators
- Logical operators
- Element query operators
- Operators on arrays

Notes:

Comparison Query Operators

- `$lt`: Exists and is less than
- `$lte`: Exists and is less than or equal to
- `$gt`: Exists and is greater than
- `$gte`: Exists and is greater than or equal to
- `$ne`: Does not exist or does but is not equal to
- `$in`: Exists and is in a set
- `$nin`: Does not exist or is not in a set

Notes:

Exercise: Comparison Operators

Experiment with the following.

```
db.testcol.drop()
for (i=1;i<=5;i++) { db.testcol.insert( { a : i } ) };
db.testcol.insert( { } )                        // No "a" field
db.testcol.find()

db.testcol.find( { a : { $gte : 2 } } )

db.testcol.find( { a : { $ne : 2 } } )

db.testcol.find( { a : { $in : [ 3, 2 ] } } } )

db.testcol.find( { a : { $nin : [ 3, 2 ] } } } )
```

Notes:

Logical Query Operators

- `$or`: Match either of two or more values
- `$not`: Used with other operators
- `$nor`: Match neither of two or more values
- `$and`: Match both of two or more values
  - This is the default behavior for queries specifying more than one condition.
  - Use `$and` if you need to include the same operator more than once in a query.

Notes:

Exercise: Logical Operators (Setup)

Create a collection we can experiment with.

```
db.testcol.drop()
for (i=1; i<=3; i++) {
    for (j=1; j<=3; j++) {
        db.testcol.insert( { a : i, b : j } )
    }
};
db.testcol.insert( { b : 10 } )  // No "a" field
db.testcol.find()
```

Notes:

Exercise: Logical Operators

Experiment with the following.

```
db.testcol.find( { $or : [ { a : 1 }, { b : 2 } ] } )

db.testcol.find( { a : { $not : { $gt : 3 } } } )

db.testcol.find( { $nor : [ { a : 3 } , { b : 3 } ] } )

db.testcol.find( { b : { $gt : 2 , $lte : 10 } } )  // and is implicit

db.testcol.find( { $and : [ { $or : [ { a : 1 }, { a : 2 } ] },
                            { $or : [ { b : 2 }, { b : 3 } ] } ] } )
```

Notes:

Element Query Operators

- `$exists`: Select documents based on the existence of a particular field.
- `$type`: Select documents based on their type.
- See BSON types[3] for reference on types.

Notes:

Exercise: Element Operators

Experiment with the following.

```
db.testcol.drop()
// by default, the mongo shell treats numbers as floating-point values
db.testcol.insert( [ { a : 1 }, { b : 1 }, { a : NumberInt(2) },
                     { b : "b" } ] )

db.testcol.find( { a : { $exists : true } } )

// type 1 is Double
db.testcol.find( { b : { $type : 1 } } )

// type 2 is String
db.testcol.find( { b : { $type : 2 } } )

// type 16 is 32-bit integer
// use NumberInt(), NumberLong() to handle integers in the mongo shell
db.testcol.find( { a : { $type : 16 } } )
```

Notes:

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

Array Query Operators

- `$all`: Array field must contain all values listed.
- `$size`: Array must have a particular size. E.g., `$size : 2` means 2 elements in the array
- `$elemMatch`: All conditions must be matched by at least one element in the array

Notes:

Exercise: Array Operators

Experiment with the following.

```
db.testcol.drop()
db.testcol.insert( [ { a : [ 1, 2, 3, 4, 5 ] },
                     { a : [ 1, 5 ] },
                     { a : [ 1, 3, 5 ] } ] )

db.testcol.find( { a : { $all : [ 1, 2 ] } } )

db.testcol.find( { a : { $size : 3 } } )

// at least one element must match both conditions
db.testcol.find( { a : { $elemMatch : { $gte : 2, $lte : 4 } } } )

// at least one element must match either condition
// does not need to be the same element
db.testcol.find( { a : { $gte : 2, $lte : 4 } } )
```

Notes:

2.4 Updating Documents

Learning Objectives

Upon completing this module students should understand

- The `update()` method
- The required parameters for `update()`
- Field update operators
- Array update operators
- The concept of an upsert and use cases.

Notes:

The `update()` Method

- Mutate documents in MongoDB using `update()`.
- `update()` requires two parameters:
  - A query document used to select documents to be updated
  - An update document that specifies how selected documents will change
- `update()` cannot delete a document.

Notes:

Parameters to `update()`

- Keep the following in mind regarding the required parameters for `update()`
- The query parameter:
  - Use the same syntax as with `find()`.
  - By default only the first document found is updated.
- The update parameter:
  - Take care to simply modify documents if that is what you intend.
  - Replacing documents in their entirety is easy to do by mistake.

Notes:

`$set` and `$unset`

- Update one or more fields using the `$set` operator.
- If the field already exists, using `$set` will change its value.
- If the field does not exist, `$set` will create it and set it to the new value.
- Any fields you do not specify will not be modified.
- You can remove a field using `$unset`.

Notes:

Exercise: `$set` and `$unset`

Experiment with the following. Do a `find()` after each update to view the results.

```
db.testcol.drop()
for (i=1; i<=5; i++) { db.testcol.insert( { _id : i, a : i, b : i } ) }

db.testcol.update( { _id : 3 }, { $set : { a : 6 } } )

db.testcol.update( { _id : 5 } , { $set : { c : 5 } } )

db.testcol.update( { _id : 5 } , { $set : { c : 7 , a : 7 } } )

db.testcol.update( { _id : 5 } , { d : 4 } )

db.testcol.update( { _id : 4 } , { $unset :  { a : 1 } } )
```

Notes:

Update Operators

- `$inc`: Increment a field's value by the specified amount.
- `$mul`: Multiply a field's value by the specified amount.
- `$rename`: Rename a field.
- `$set` (already discussed)
- `$unset` (already discussed)
- `$min`: Update only if value is smaller than specified quantity
- `$max`: Update only if value is larger than specified quantity
- `$currentDate`: Set the value of a field to the current date or timestamp.

Notes:

Exercise: Update Operators

Experiment with the following update operators.

```
db.testcol.drop()
for (i=1; i<=5; i++) { db.testcol.insert( { _id : i, a : i, b : i } ) }
db.testcol.find()

db.testcol.update( { _id : 2 }, { $inc : { a : -3 } } )

db.testcol.update( { _id : 1 }, { $inc : { q : 1 } } )

db.testcol.update( { _id : 3 }, { $mul : { a : 4 } } )

db.testcol.update( { _id : 4 }, { $rename : { a : "xyz" } } )

db.testcol.update( { _id : 5 }, { $min : { a : 3 } } )

db.testcol.update( { _id : 1 },
                   { $currentDate : { c : { $type : "timestamp" } } } )
```

Notes:

`update()` Defaults to one Document

- By default, `update()` modifies the first document found that matches the query.
- The default use case is one where there is only one document that fits the query.
- This is to reduce the chances of unintended collection scans for updates.

Notes:

Updating Multiple Documents

- In order to update multiple documents, we use the third (optional) parameter to `update()`.
- The third parameter is an options document.
- Specify `multi: true` as one field in this document.
- Bear in mind that without an appropriate index, you may scan every document in the collection.

Notes:

Exercise: Multi-Update

Use `db.testcol.find()` after each of these updates.

```
db.testcol.drop()
for (i=1; i<=5; i++) { db.testcol.insert( { _id : i, a : i } ) }

db.testcol.update( { _id : { $lt : 5 } }, { $set : { a : 6 } } )

db.testcol.update( { _id : { $lt : 5 } }, { $set : { a : 7 } },
                   { multi : true } )
```

Notes:

Array Operators

- `$push`: Appends an element to the end of the array.
- `$pushAll`: Appends multiple elements to the end of the array.
- `$pop`: Removes one element from the end of the array.
- `$pull`: Removes all elements in the array that match a specified value.
- `$pullAll`: Removes all elements in the array that match any of the specified values.
- `$addToSet`: Appends an element to the array if not already present.

Notes:

Exercise: Array Operators

Experiment with the following updates.

```
db.testcol.drop()
for (i=1; i<=5; i++) { db.testcol.insert(
    { _id : i, a : i, b: [ 1, 2, 3, 3, "NA", 6 ] } ) }

db.testcol.update( { _id : 1 }, { $push : { b : 3 } } )
db.testcol.update( { _id : 2 }, { $pushAll : { b : [ 1, 2, 3 ] } } )

db.testcol.update( { _id : 2 }, { $pop : { b : "" } } )

db.testcol.update( { _id : 3 }, { $pull : { b : 3 } } )
db.testcol.update( { _id : 4 },
                   { $pullAll : { b : [ 1, 2, "NA", 4 ] } } )

db.testcol.update( { _id : 5 }, { $addToSet : { b : 2 } } )
db.testcol.update( { _id : 5 }, { $addToSet : { b : 4 } } )
```

Notes:

The Positional `$` Operator

- $[4] is a positional operator that specifies an element in an array to update.
- It acts as a placeholder for the first element that matches the query document.
- `$` replaces the element in the specified position with the value given.
- Example:

```
db.collection.update(
    { <array> : value ... },
    { <update operator> : { "<array>.$" : value } }
)
```

Notes:

[4] http://docs.mongodb.org/manual/reference/operator/update/postional

Exercise: The Positional $ Operator

Experiment with the following commands.

```
db.testcol.drop()
for (i=1; i<=5; i++) { db.testcol.insert(
    { _id: i, a: i, b: [ 1, 2, 3, 3, "NA", 6 ] } ) }
db.testcol.find()

db.testcol.update( { b: "NA" }, { $set: { "b.$" : 11 } },
                   { multi: true } )
db.testcol.find()
```

Notes:

Upserts

- By default, if no document matches an update query, the `update()` method does nothing.
- By specifying `upsert: true`, `update()` will insert a new document if no matching document exists.
- The `db.collection.save()` method is syntactic sugar that performs an upsert if the _id is not yet present
- Syntax:

```
db.collection.update( <query document>, <update document>,
                      { upsert: true } )
```

Notes:

Upsert Mechanics

- Will update as usual if documents matching the query document exist.
- Will be an upsert if no documents match the query document.
  - MongoDB creates a new document using equality conditions in the query document.
  - Adds an `_id` if the query did not specify one.
  - Performs an update on the new document.

Notes:

Exercise: Upserts

Experiment with the following upserts.

```
db.testcol.drop()
for (i=1; i<=5; i++) {
    db.testcol.insert( { _id: i, a: i, b: i } ) }
db.testcol.find()

db.testcol.update( { a: 4 }, { $inc: { b : 3 } }, { upsert: true } )

db.testcol.update( { a: 12 }, { $inc: { b : 3 } }, { upsert: true } )

db.testcol.update( { _id: 6, a: 6 }, { c: 155 }, { upsert: true } )
```

Notes:

`save()`

- Updates the document if the _id is found, inserts it otherwise
- Syntax:

  ```
  db.collection.save( document )
  ```

Notes:

Exercise: `save()`

```
db.testcol.drop()
for (i=1; i<=5; i++) { db.testcol.save( { _id : i, a : i, b : i } ) }
db.testcol.find()

// Look at the code for save. Note that it involves an upsert.
db.testcol.save

// new document, _id created
db.testcol.save( { a : 3 } )

db.testcol.save( { _id : 6, a : 6 } )             // new document

db.testcol.save( { _id : 3, a : 12, b : 12  } )   // update!!
```

Notes:

Be Careful with `save()`

Be careful that you are not modifying stale data when using `save()`. For example:

```
db.testcol.drop()
db.testcol.insert( { _id : 2, a : 2, b : 2 } )

db.testcol.find( { _id : 2 } )
doc = db.testcol.findOne( { _id: 2 } )

db.testcol.update( { _id: 2 }, { $inc: { b : 1 } } )
db.testcol.find()

doc.c = 11
doc

db.testcol.save(doc)  // just lost our incrementing of b.
db.testcol.find()
```

Notes:

3 Indexes

3.1 Index Fundamentals

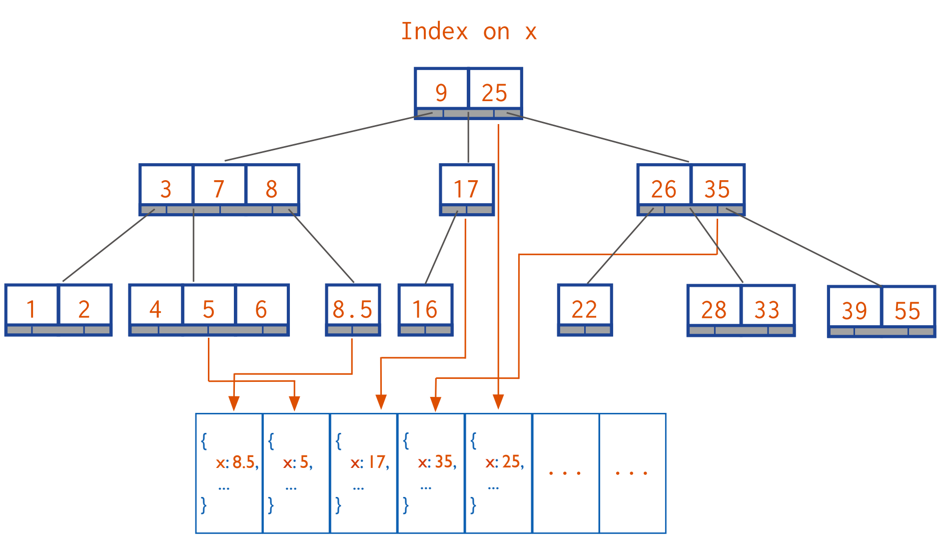
Learning Objectives

Upon completing this module students should understand:

- The impact of indexing on read performance
- The impact of indexing on write performance
- How to choose effective indexes
- The utility of specific indexes for particular query patterns

Notes:

Why Indexes?



Notes:

Types of Indexes

- Single-field indexes
- Compound indexes
- Multikey indexes
- Geospatial indexes
- Text indexes

Notes:

Exercise: Using `explain()`

- Let's explore what MongoDB does for the following query by using `explain()`.
- We are projecting only `user.name` so that the results are easy to read.

```
db.tweets.find( { "user.followers_count" : 1000 },
                { "_id" : 0, "user.name": 1 } )

db.tweets.find( { "user.followers_count" : 1000 } ).explain()
```

Notes:

Results of `explain()`

You will see results similar to the following.

```
{
    "cursor" : "BasicCursor",
    "isMultiKey" : false,
    "n" : 8,
    "nscannedObjects" : 51428,
    "nscanned" : 51428,
    "nscannedObjectsAllPlans" : 51428,
    "nscannedAllPlans" : 51428,
    "scanAndOrder" : false,
    "indexOnly" : false,
    "nYields" : 401,
    "nChunkSkips" : 0,
    "millis" : 161,
    "server" : "new-host-3.home:27017",
    "filterSet" : false
}
```

Notes:

Understanding `explain()` Output

- `n` displays the number of documents that match the query.
- `nscannedObjects` displays the number of documents the retrieval engine considered during the query.
- `nscanned` displays how many documents in an existing index were scanned.
- An `nscanned` value much higher than `nreturned` indicates we need a different index.
- Given `nscannedObjects`, this query will benefit from an index.

Notes:

Single-Field Indexes

- Based on a single field of the documents in a collection
- The field may be a top-level field
- You may also create an index on fields in embedded documents

Notes:

Creating an Index

- The following creates a single-field index on `user.followers_count`.
- `explain()` indicated there will be a substantial performance improvement in handling this type of query.

```
db.tweets.ensureIndex( { "user.followers_count" : 1 } )
db.tweets.find( { "user.followers_count" : 1000 } ).explain()
```

Notes:

Indexes and Read/Write Performance

- Indexes improve read performance for queries that are supported by the index.
- Inserts will be slower when there are indexes that MongoDB must also update.
- The speed of updates may be improved because MongoDB will not need to do a collection scan to find target documents.
- An index is modified any time a document:
  - Is inserted
  - Is deleted
  - Is updated in such a way that its indexed field changes
  - If an update causes a document to move on disk

Notes:

Index Limitations

- You can have up to 64 indexes per collection.
- You should NEVER be anywhere close to that upper bound.
- Write performance will degrade to unusable at somewhere between 20-30.

Notes:

Use Indexes with Care

- Every query should use an index.
- Every index should be used by a query.
- Any write operation that touches an indexed field will require each index to be updated.
- Indexes require RAM.
- Be judicious about the choice of key.

Notes:

3.2 Compound Indexes

Learning Objectives

Upon completing this module students should understand:

- What a compound index is.
- How compound indexes are created.
- The importance of considering field order when creating compound indexes.
- How to efficiently handle queries involving some combination of equality matches, ranges, and sorting.
- Some limitations on compound indexes.

Notes:

Introduction to Compound Indexes

- It is common to create indexes based on more than one field.
- These are called `compound indexes`.
- You may use up to 31 fields in a compound index.
- You may not use hashed index fields.

Notes:

The Order of Fields Matters

Specifically we want to consider how the index will be used for:

- Equality tests, e.g.,

  ```
  db.example.find( { a : 15, b : 17 } )
  ```

- Range queries, e.g.,

  ```
  db.example.find( { a : 15, b : { $lt : 85 } } )
  ```

- Sorting, e.g.,

  ```
  db.example.find( { a : 15, b : 17 } ).sort( { b : -1 } )
  ```

Notes:

Designing Compound Indexes

- Let's look at some guiding principles for building compound indexes.
- These will generally produce a good if not optimal index.
- You can optimize after a little experimentation.
- We will explore this in the context of a running example.

Notes:

Example: A Simple Message Board

Requirements:

- Find all messages in a specified timestamp range.
- Select for whether the messages are anonymous or not.
- Sort by rating from highest to lowest.

Notes:

Load the Data

```
a = [ { "timestamp" : 1, "username" : "anonymous", "rating" : 3 },
      { "timestamp" : 2, "username" : "anonymous", "rating" : 5 },
      { "timestamp" : 3, "username" : "sam", "rating" : 1 },
      { "timestamp" : 4, "username" : "anonymous", "rating" : 2 },
      { "timestamp" : 5, "username" : "martha", "rating" : 5 } ]
db.messages.insert(a)
```

Notes:

Start with a Simple Index

Start by building an index on { timestamp : 1 }

```
db.messages.ensureIndex( { timestamp : 1 }, { name : "myindex" } )
```

Now let's query for messages with timestamp in the range 2 through 4 inclusive.

```
db.messages.find( { timestamp : { $gte : 2, $lte : 4 } } ).explain()
```

Notes:

Query Adding `username`

```
db.messages.find( { timestamp : { $gte : 2, $lte : 4 },
                    username : "anonymous" } ).explain()
```

Notes:

Include `username` in Our Index

```
db.messages.dropIndex( "myindex" );
db.messages.ensureIndex( { timestamp : 1, username : 1 },
                         { name : "myindex" } )
db.messages.find( { timestamp : { $gte : 2, $lte : 4 },
                    username : "anonymous" } ).explain()
```

Notes:

`ncanned` > n

timestamp	username
1	“anonymous”
2	“anonymous”
3	“sam”
4	“anonymous”
5	“martha”

Notes:

A Different Compound Index

Drop the index and build a new one with user.

```
db.messages.dropIndex( "myindex" );
db.messages.ensureIndex( { username : 1 , timestamp : 1 },
                         { name : "myindex" } )
db.messages.find( { timestamp : { $gte : 2, $lte : 4 },
                    username : "anonymous" } ).explain()
```

Notes:

`nscanned == n ==` 2

username	timestamp
“anonymous”	1
“anonymous”	2
“anonymous”	4
“sam”	2
“martha”	5

Notes:

Let Selectivity Drive Field Order

- Order fields in a compound index from most selective to least selective.
- Usually, this means equality fields before range fields.
- When dealing with multiple equality values, start with the most selective.
- If a common range query is more selective instead (rare), specify the range component first.

Notes:

Adding in the Sort

Finally, let's add the sort and run the query.

```
db.messages.find( {
                    timestamp : { $gte : 2, $lte : 4 },
                    username : "anonymous"
                  } ).sort( { rating : -1 } ).explain();
```

Notes:

In-Memory Sorts

Let's modify the index again to allow the database to sort for us.

```
db.messages.dropIndex( "myindex" );
db.messages.ensureIndex( { username : 1 , timestamp : 1, rating : 1 },
                         { name : "myindex" } );
db.messages.find( {
                    timestamp : { $gte : 2, $lte : 4 },
                    username : "anonymous"
                  } ).sort( { rating : -1 } ).explain();
```

Notes:

Avoiding an In-Memory Sort

Rebuild the index as follows.

```
db.messages.dropIndex( "myindex" );
db.messages.ensureIndex( { username : 1, rating : 1, timestamp : 1 },
                         { name : "myindex" } );
db.messages.find( {
                    timestamp : { $gte : 2, $lte : 4 },
                    username : "anonymous"
                  } ).sort( { rating : -1 } ).explain();
```

Notes:

General Rules of Thumb

- Equality before range.
- Equality before sorting.
- Sorting before range.

Notes:

3.3 Multikey Indexes

Learning Objectives

Upon completing this module, students should understand:

- What a multikey index is
- When MongoDB will use a multikey index to satisfy a query
- How multikey indexes work
- How multikey indexes handle sorting
- Some limitations on multikey indexes

Notes:

Introduction to Multikey Indexes

- A multikey index is an index on an array.
- An index entry is created on each value found in the array.
- Multikey indexes can support primitives, documents, or sub-arrays.
- There is nothing special that you need to do to create a multikey index.
- You created them using `ensureIndex()` just as you would with an ordinary single-field index.
- If there is an array as a value for an indexed field, the index will be multikey on that field.

Notes:

Example: Array of Numbers

```
db.testcol.drop()
db.testcol.ensureIndex( { x : 1 } )
a = [ { x : [ 1, 2, 3 ], y : [ "a", "b" ] },
      { x : [ 3, 4 ], y : [ "a", "b" ] },
      { x : [ 4, 5 ], y : [ "a", "b" ] },
      { x : 3, y : [ "a", "b" ] }, { x : 4, y : [ "a", "b" ] } ]
db.testcol.insert( a )
db.testcol.find( { x : 3 } )
db.testcol.find( { x : 3 } ).explain()
db.testcol.find( { "x.2" : 3 } )
db.testcol.find( { "x.2" : 3 } ).explain()
```

Notes:

Exercise: Array of Documents, Part 1

Create a collection and add an index on the `x` field:

```
db.testcol.drop()
b = [ { x : [ { name : "Alice", number : 1 }, { name : "Bob", number : 2 },
              { name : "Cherry", number : 3 } ] },
      { x : [ { name : "Cherry", number : 3 },
              { name : "Dan", number : 4 } ] },
      { x : [ { name : "Dan", number : 4 },
              { name : "Erica", number : 5 } ] },
      { x : { name : "Cherry", number : 3 } },
            { name : "Dan", number : 4 } ]
db.testcol.insert(b)
db.testcol.ensureIndex( { x : 1 } )
db.testcol.find()
```

Notes:

Exercise: Array of Documents, Part 2

For each of the three queries below:

- How many documents will be returned?
- Will it use our multi-key index? Why or why not?
- If a query will not use the index, which index will it use?

```
db.testcol.find( { x : { name : "Cherry", number : 3 } } )
db.testcol.find( { x : { number : 3 } } )
db.testcol.find( { "x.number" : 3 } )
```

Notes:

Exercise: Array of Arrays, Part 1

Add some documents and create an index:

```
db.testcol.drop()
db.testcol.ensureIndex( { x : 1 } )
c = [ { x : [ [ 1, 2 ], [ 2, 3 ], [ 3, 4] ] },
      { x : [ [ 3, 4 ], [ 4, 5 ] ] },
      { x : [ [ 4, 5 ], [ 5, 6 ] ] },
      { x : [ 3, 4 ] },
      { x : [ 4, 5 ] } ]
db.testcol.insert(c)
db.testcol.find()
```

Notes:

Exercise: Array of Arrays, Part 2

For each of the queries below:

- How many documents will be returned?
- Does the query use the multi-key index? Why or why not?
- If the query does not use the index, what is an index it could use?

```
db.testcol.find( { x : [ 3, 4 ] } )
db.testcol.find( { x : 3 } )
db.testcol.find( { "x.1" : [ 4, 5 ] } )
db.testcol.find( { "x.1" : 4 } )
```

Notes:

How Multikey Indexes Work

- Each array element is given one entry in the index.
- So an array with 17 elements will have 17 entries – one for each element.
- Multikey indexes can take up much more space than standard indexes.

Notes:

Multikey Indexes and Sorting

- If you sort using a multikey index:
  - A document will appear at the first position where a value would place the document.
  - It does not appear multiple times.
- This applies to array values generally.
- It is not a specific property of multikey indexes.

Notes:

Exercise: Multikey Indexes and Sorting

```
db.testcol.drop()
a = [ { x : [ 1, 11 ] }, { x : [ 2, 10 ] }, { x : [ 3 ] },
      { x : [ 4 ] }, { x : [ 5 ] } ]
db.testcol.insert(a)

db.testcol.ensureIndex( { x : 1 } )

// x : [ 1, 11 ] array comes first. It contains the lowest value.
db.testcol.find().sort( { x : 1 } )

// x : [ 1, 11 ] array still comes first. Contains the highest value.
db.testcol.find().sort( { x : -1 } )
```

Notes:

Limitations on Multikey Indexes

- You cannot create a compound index using more than one array-valued field.
- This is because of the combinatorics.
- For a compound index on two array-valued fields you would end up with N * M entries for one document.
- You cannot have a hashed multikey index.
- You cannot have a shard key use a multikey index
- We discuss shard keys in another module.
- The index on the _id field cannot become a multikey index.

Notes:

Example: Multikey Indexes on Multiple Fields

```
db.testcol.drop()
db.testcol.ensureIndex( { x : 1, y : 1 } )

// no problems yet
db.testcol.insert( { _id : 1, x : 1, y : 1 } )

// still OK
db.testcol.insert( { _id : 2, x : [ 1, 2 ], y : 1 } )

// still OK
db.testcol.insert( { _id : 3, x : 1, y : [ 1, 2 ] } )

// Won't work
db.testcol.insert( { _id : 4, x : [ 1, 2 ], y : [ 1, 2 ] } )
```

Notes:

3.4 Hashed Indexes

Learning Objectives

Upon completing this module, students should understand:

- What a hashed index is.
- When to use one.

Notes:

What is a Hashed Index?

- Hashed indexes are based on field values like any other index.
- The difference is that the values are hashed and it is the hashed value that is indexed.
- The hashing function collapses sub-documents and computes the hash for the entire value.
- MongoDB can use the hashed index to support equality queries.
- Hashed indexes do not support multi-key indexes, i.e. indexes on array fields.
- Nor do they support range queries.

Notes:

Why Hashed Indexes?

- In MongoDB, the primary use for hashed indexes is to support sharding a collection using a hashed shard key.
- In some cases, the field we would like to use to shard data would make it difficult to scale using sharding.
- Using a hashed shard key to shard a collection ensures an even distribution of data and overcomes this problem.
- See Shard a Collection Using a Hashed Shard Key[5] for more details.
- We discuss sharding in detail in another module.

Notes:

Limitations

- You may not create compound indexes that have hashed index fields
- You may not specify a unique constraint on a hashed index
- You can create both a hashed index and a non-hashed index on the same field.

Notes:

Floating Point Numbers

- MongoDB hashed indexes truncate floating point numbers to 64-bit integers before hashing.
- Do not use a hashed index for floating point numbers that cannot be reliably converted to 64-bit integers.
- MongoDB hashed indexes do not support floating point values larger than 2^{53}.

Notes:

[5] http://docs.mongodb.org/manual/tutorial/shard-collection-with-a-hashed-shard-key/

Creating a Hashed Index

Create a hashed index using an operation that resembles the following. This operation creates a hashed index for the active collection on the `a` field.

```
db.active.ensureIndex( { a: "hashed" } )
```

Notes:

4 Aggregation

Aggregation Tutorial **(page 69)** An introduction to the the aggregation framework, pipeline concept, and stages.

Optimizing Aggregation **(page 81)** Resource management in the aggregation pipeline.

4.1 Aggregation Tutorial

Learning Objectives

Upon completing this module students should understand:

- The concept of the aggregation pipeline
- The stages of the aggregation pipeline
- How to use aggregation operators
- The fundamentals of using aggregation for data analysis
- Group aggregation operators
- Using the same operator in multiple stages of an aggregation pipeline

Notes:

Aggregation Basics

- Use the aggregation framework to transform and analyze data in MongoDB collections.
- For those who are used to SQL, aggregation can be similar to `GROUP BY`.
- The aggregation framework is based on the concept of a pipeline.

Notes:

The Aggregation Pipeline

- An aggregation pipeline in analogous to a UNIX pipeline.
- Each stage of the pipeline:
  - Receives a set of documents as input.
  - Performs an operation on those documents.
  - Produces a set of documents for use by the following stage.
- A pipeline has the following syntax:

```
db.collection.aggregate( [ { stage1 }, { stage2 }, ... ],
                         { options } )
```

Notes:

Aggregation Stages

- `$match`: Similar to `find()`
- `$project`: Shape documents
- `$sort`: Like the cursor method of the same name
- `$skip`: Like the cursor method of the same name
- `$limit`: Like the cursor method of the same name
- `$unwind`: Used for working with arrays
- `$group`: Used to aggregate field values from multiple documents
- `$out`: Creates a new collection from the output of an aggregation pipeline)

Notes:

The Match Stage

- The `$match` operator works like the query phase of `find()`, `update()`, and `remove()`.
- Documents in the pipeline that match the query document will be passed to subsequent stages.
- `$match` is often the first operator used in an aggregation stage.
- Like other aggregation operators, `$match` can occur multiple times in a single pipeline.

Notes:

Exercise: The Match Stage

Select only the first two documents using a match stage in an aggregation pipeline.

```
a = [ { _id : 1, a : 1 }, { _id : 2, a : 2 }, { _id : 3, a : 3 },
      { _id : 4, a : 4 }, { _id : 5, a : 5 } ]
db.testcol.insert( a )

// 2 docs are output from the aggregation pipeline
db.testcol.aggregate( [ { $match : { a : { $lte : 2 } } } ] )
```

Notes:

The Project Stage

- $project allows you to shape the documents into what you need for the next stage.
- The simplest form of shaping is using $project to select only the fields you are interested in.
- $project can also create new fields from other fields in the input document.
  - *E.g.*, you can pull a value out of an embedded document and put it at the top level.
  - *E.g.*, you can create a ratio from the values of two fields as pass along as a single field.
- $project produces 1 output document for every input document it sees.

Notes:

Exercise: Selecting fields with $project

Use the $project operator to pass specific fields in output documents.

```
db.testcol.drop()
for ( var i=1; i<=10; i++ ) {
    db.testcol.insert( { a : i, b : i*2, c : { d : i*4, e : i*8 } } ) }
db.testcol.find()

db.testcol.aggregate( [ { $project : { a : 1 } } ] )

db.testcol.aggregate( [ { $project : { _id : 0, a : 1 } } ] )

db.testcol.aggregate( [ { $project : { a : 1, "c.d": 1 } } ] )
```

Notes:

Exercise: Renaming fields with $project

Use the $project operator to rename a field

```
db.testcol.aggregate( [ { $project : { _id : 0,
                                       sequenceNumber : "$a",
                                       b : 1 } } ] )
```

Notes:

Exercise: Shaping documents with $project

Experiment with the following projections.

```
db.testcol.aggregate( [ { $project : { a : 1, b : 1, d : "$c.d" } } ] )

db.testcol.aggregate( [ { $project : { sequenceNumber : "$a",
                                       ratio : { $divide : [ "$c.d", "$c.e" ] } } } ] )
```

More about $divide[6] in another lesson.

Notes:

[6] http://docs.mongodb.org/manual/reference/operator/aggregation/divide/

A Twitter Dataset

- We now have a basic understanding of the aggregation framework.
- Let’s look at some richer examples that illustrate the power of MongoDB aggregation.
- These examples operate on a collection of tweets.
  - As with any dataset of this type, it’s a snapshot in time.
  - It may not reflect the structure of Twitter feeds as they look today.

Notes:

Tweets Data Model

```
{
    "text" : "Something interesting ...",
    "entities" : {
        "user_mentions" : [
            {
                "screen_name" : "somebody_else",
                ...
            }
        ],
        "urls" : [ ],
        "hashtags" : [ ]
    },
    "user" : {
        "friends_count" : 544,
        "screen_name" : "somebody",
        "followers_count" : 100,
        ...
    },
}
```

Notes:

Analyzing Tweets

- Imagine the types of analyses one might want to do on tweets.
- It's common to analyze the behavior of users and the networks involved.
- Our examples will focus on this type of analysis

Notes:

Friends and Followers

- Let's look again at two stages we touched on earlier:
  - `$match`
  - `$project`
- In our dataset:
  - `friends` are those a user follows.
  - `followers` are others that follow a users.
- Using these operators we will write an aggregation pipeline that will:
  - Ignore anyone with no friends and no followers.
  - Calculate who has the highest followers to friends ratio.

Notes:

Exercise: Friends and Followers

```
db.tweets.aggregate( [
    { $match: { "user.friends_count": { $gt: 0 },
                "user.followers_count": { $gt: 0 } } },
    { $project: { ratio: {$divide: ["$user.followers_count",
                                    "$user.friends_count"]},
                  screen_name : "$user.screen_name"} },
    { $sort: { ratio: -1 } },
    { $limit: 1 } ] )
```

Notes:

Exercise: $match and $project

- Of the users in the "Brasilia" timezone who have tweeted 100 times or more, who has the largest number of followers?
- Time zone is found in the "time_zone" field of the user object in each tweet.
- The number of tweets for each user is found in the "statuses_count" field.
- Your result document should look something like the following:

```
{ u'_id': ObjectId('52fd2490bac3fa1975477702'),
  u'followers': 2597,
  u'screen_name': u'marbles',
  u'tweets': 12334}
```

Notes:

The Group Stage

- For those coming from the relational world, `$group` is similar to the SQL `GROUP BY` statement.
- $group operations require that we specify which field to group on.
- Documents with the same identifier will be aggregated together.
- With $group, we aggregate values using arithmetic or array operators.

Notes:

Group using $avg

```
db.testcol.aggregate( [ { $group : { _id : { a : "$a" },
                                     b_avg : { $avg : "$b" } } } ] )
```

Notes:

Group using $push

For each user, aggregate all their tweets into a single array.

```
db.tweets.aggregate( [
   { "$group" : { "_id" : "$user.screen_name",
                  "tweet_texts" : { "$push" : "$text" },
                  "count" : { "$sum" : 1 } } },
   { "$sort" : { "count" : -1 } },
   { "$limit" : 5 }
] )
```

Notes:

Group Aggregation Operators

The complete list of operators available in the group stage:

- $addToSet
- $first
- $last
- $max
- $min
- $avg
- $push
- $sum

Notes:

Rank Users by Number of Tweets

- One common task is to rank users based on some metric.
- Let's look at who tweets the most.
- We will use the aggregation framework to do this.

Notes:

Process

- Group together all tweets by a user for every user in our collection
- Count the tweets for each user
- Sort in decreasing order

Notes:

Exercise: Ranking Users by Number of Tweets

Try this aggregation pipeline for yourself.

```
db.tweets.aggregate( [
    { $group: { _id: "$user.screen_name",
                count: { $sum: 1 } } },
    { $sort: { count: -1 } }
] )
```

Notes:

Exercise: Tweet Source

- The tweets in our twitter collection have a field called `source`.
- This field describes the application that was used to create the tweet.
- Write an aggregation pipeline that identifies the applications most frequently used to publish tweets.

Notes:

The Unwind Stage

- In many situations we want to aggregate using values in an array field.
- In our tweets dataset we need to do this to answer the question:
  - "Who includes the most user mentions in their tweets?"
- User mentions are stored as within an embedded document for entities.
- This embedded document also lists any urls and hashtags used in the tweet.

Notes:

Example: User Mentions in a Tweet

```
...
"entities" : {
    "user_mentions" : [
        {
            "indices" : [
                28,
                44
            ],
            "screen_name" : "LatinsUnitedGSX",
            "name" : "Henry Ramirez",
            "id" : 102220662
        }
    ],
    "urls" : [ ],
    "hashtags" : [ ]
 },
 ...
```

Notes:

Using $unwind

Who includes the most user mentions in their tweets?

```
db.tweets.aggregate(
    { $unwind: "$entities.user_mentions" },
    { $group: { _id: "$user.screen_name",
                count: { $sum: 1 } } },
    { $sort: { count: -1 } },
    { $limit: 1 })
```

Notes:

Data Processing Pipelines

- The aggregation framework allows you to create a data processing pipeline.
- You can include as many stages as necessary to achieve your goal.
- For each stage consider:
  - What input that stage must receive
  - What output it should produce.
- Many tasks require us to include more than one stage using a given operator.

Notes:

Most Unique User Mentions

- We frequently need multiple group stages to achieve our goal.
- We just looked at a pipeline to find the tweeter that mentioned the most users.
- Let's change this so that it is more of a question about a tweeter's active network.
- We might ask which tweeter has mentioned the most unique users in their tweets.

Notes:

Same Operator ($group), Multiple Stages

Which tweeter has mentioned the most unique users in their tweets?

```
db.tweets.aggregate( [
    { $unwind: "$entities.user_mentions" },
    { $group: {
        _id: "$user.screen_name",
        mset: { $addToSet: "$entities.user_mentions.screen_name"  } } },
    { $unwind: "$mset"},
    { $group: { _id: "$_id", count: { $sum: 1 } } },
    { $sort: { count: -1 } },
    { $limit: 1 }
] )
```

Notes:

The Sort Stage

- Uses the $sort operator
- Works like the `sort()` cursor method
- 1 to sort ascending; -1 to sort descending
- E.g, db.testcol.aggregate([{ $sort : { b : 1, a : -1 } }])

Notes:

The Skip Stage

- Uses the $skip operator
- Works like the `skip()` cursor method.
- Value is an integer specifying the number of documents to skip.
- E.g, the following will pass all but the first 3 documents to the next stage in the pipeline.
  - db.testcol.aggregate([{ $skip : 3 }, ...])

Notes:

The Limit Stage

- Used to limit the number of documents passed to the next aggregation stage.
- Works like the `limit()` cursor method.
- Value is an integer.
- E.g., the following will only pass 3 documents to the stage that comes next in the pipeline.
  - db.testcol.aggregate([{ $limit: 3 }, ...])

Notes:

The Out Stage

- Used to create a new collection from the output of the aggregation pipeline.
- Can only be the last stage in the pipeline.
- If a collection by the name already exists, it replaces that collection.
- Syntax is { $out : "collection_name" }

Notes:

4.2 Optimizing Aggregation

Learning Objectives

Upon completing this module students should understand:

- Aggregation pipeline options
- Key aspects of resource management during the aggregation pipeline
- How to order aggregation stages to maximize speed and minimize resource usage
- How MongoDB automatically reorders pipeline stages to improve efficiency
- Changes in the aggregation framework from MongoDB 2.4 to 2.6.

Notes:

Aggregation Options

- You may pass an options document to `aggregate()`.
- Syntax:

```
db.collection.aggregate( [ { stage1 }, { stage2 }, ... ], { options } )
```

- Following are some of the fields that may be passed in the options document.
  - `allowDiskUse : true` - permit the use of disk for memory-intensive queries
  - `explain : true` - display how indexes are used to perform the aggregation.

Notes:

Aggregation Limits

- An aggregation pipeline cannot use more than 100 MB of RAM.
- `allowDiskUse : true` allows you to get around this limit.
- The follow operators do not require the entire dataset to be in memory:
  - $match, $skip, $limit, $unwind, and $project
  - Stages for these operators are not subject to the 100 MB limit.
  - $unwind can, however, dramatically increase the amount of memory used.
- $group and $sort might require all documents in memory at once.

Notes:

Limits Prior to MongoDB 2.6

- `aggregate()` returned results in a single document up to 16 MB in size.
- The upper limit on pipeline memory usage was 10% of RAM.

Notes:

Optimization: Reducing Documents in the Pipeline

- These operators can reduce the number of documents in the pipeline:
  - $match
  - $skip
  - $limit:
- They should be used as early as possible in the pipeline.

Notes:

Optimization: Sorting

- `$sort` can take advantages of indexes.
- Must be used before any of the following to do this:
  - `$group`
  - `$unwind`
  - `$project`
- After these stages, the fields or their values change.
- `$sort` requires a full scan of the input documents.

Notes:

Automatic Optimizations

MongoDB will perform some optimizations automatically. For example:

- If a `$project` stage is used late in the pipeline it may be used to eliminate those fields earlier if possible.
- A `$sort` followed by a `$match` will be executed as a `$match` followed by a `$sort` to reduce the number of documents to be sorted.
- A `$skip` followed by a `$limit` will be executed as a `$limit` followed by a `$skip`, with the $limit parameter increased by the $skip amount to allow $sort + $limit coalescence.
- See: Aggregation Pipeline Optimation[7]

Notes:

[7] http://docs.mongodb.org/manual/core/aggregation-pipeline-optimization/

5 Schema Design

5.1 Schema Design Core Concepts

Learning Objectives

Upon completing this module, students should understand:

- Basic schema design principles for MongoDB
- Tradeoffs for embedded documents in a schema
- Tradeoffs for linked documents in a schema
- The use of array fields as part of a schema design

Notes:

What is a schema?

- Maps concepts and relationships to data
- Sets expectations for the data
- Minimizes overhead of iterative modifications
- Ensures compatibility

Notes:

Example: Normalized Data Model

```
User:          Book:          Author:
- username     - title        - firstName
- firstName    - isbn         - lastName
- lastName     - language
               - createdBy
               - author
```

Notes:

Example: Denormalized Version

```
User:          Book:
- username     - title
- firstName    - isbn
- lastName     - language
               - createdBy
               - author
                 - firstName
                 - lastName
```

Notes:

Schema Design in MongoDB

- Schema is defined at the application-level
- Design is part of each phase in its lifetime
- There is no magic formula

Notes:

Three Considerations

- The data your application needs
- Your application's read usage of the data
- Your application's write usage of the data

Notes:

Case Study

- A Library Web Application
- Different schemas are possible.

Notes:

Author Schema

```
{
    "_id": int,
    "firstName": string,
    "lastName": string
}
```

Notes:

User Schema

```
{
    "_id": int,
    "username": string,
    "password": string
}
```

Notes:

Book Schema

```
 {  "_id": int,
    "title": string,
    "slug": string,
    "author": int,
    "available": boolean,
    "isbn": string,
    "pages": int,
    "publisher": {
        "city": string,
        "date": date,
        "name": string
    },
    "subjects": [ string, string ],
    "language": string,
    "reviews": [ { "user": int, "text": string },
                 { "user": int, "text": string } ]
}
```

Notes:

Example Documents: Author

```
{
    _id: 1,
    firstName: "F. Scott",
    lastName: "Fitzgerald"
}
```

Notes:

Example Documents: User

```
{
    _id: 1,
    username: "emily@10gen.com",
    password: "slsjfk4odk84k209dlkdj90009283d"
}
```

Notes:

Example Documents: Book

```
{   _id: 1,
    title: "The Great Gatsby",
    slug: "9781857150193-the-great-gatsby",
    author: 1,
    available: true,
    isbn: "9781857150193",
    pages: 176,
    publisher: {
        name: "Everyman's Library",
        date: ISODate("1991-09-19T00:00:00Z"),
        city: "London"
    },
    subjects: ["Love stories", "1920s", "Jazz Age"],
    language: "English",
    reviews: [ { user: 1, text: "One of the best..." },
               { user: 2, text: "It's hard to..." } ]
}
```

Notes:

Embedded Documents

- AKA sub-documents or embedded objects
- What advantages do they have?
- When should they be used?

Notes:

Example: Embedded Documents

```
{   _id: 1,
    title: "The Great Gatsby",
    slug: "9781857150193-the-great-gatsby",
    author: 1,
    available: true,
    isbn: "9781857150193",
    pages: 176,
    publisher: {
        name: "Everyman's Library",
        date: ISODate("1991-09-19T00:00:00Z"),
        city: "London"
    },
    subjects: ["Love stories", "1920s", "Jazz Age"],
    language: "English",
    reviews: [ { user: 1, text: "One of the best..." },
               { user: 2, text: "It's hard to..." } ]
}
```

Notes:

Embedded Documents: Pros and Cons

- Great for read performance
- One seek to find the document
- At most, one sequential read to retrieve from disk
- Writes can be slow if constantly adding to objects

Notes:

Linked Documents

- What advantages does this approach have?
- When should they be used?

Notes:

Example: Linked Documents

```
{   _id: 1,
    title: "The Great Gatsby",
    slug: "9781857150193-the-great-gatsby",
    author: 1,
    available: true,
    isbn: "9781857150193",
    pages: 176,
    publisher: { publisher_name: "Everyman's Library",
                 date: ISODate("1991-09-19T00:00:00Z"),
                 publisher_city: "London" },
    subjects: ["Love stories", "1920s", "Jazz Age"],
    language: "English",
    reviews: [
               { user: 1,
                 text: "One of the best..." },
               { user: 2,
                 text: "It's hard to..." } ]
}
```

Notes:

Linked Documents: Pros and Cons

- More, smaller documents
- Can make queries by ID very simple
- Accessing linked documents requires extra seeks + reads.
- What effect does this have on the system?

Notes:

Arrays

- Array of scalars
- Array of documents

Notes:

Array of Scalars

```
{   _id: 1,
    title: "The Great Gatsby",
    slug: "9781857150193-the-great-gatsby",
    author: 1,
    available: true,
    isbn: "9781857150193",
    pages: 176,
    publisher: {
        name: "Everyman's Library",
        date: ISODate("1991-09-19T00:00:00Z"),
        city: "London"
    },
    subjects: ["Love stories", "1920s", "Jazz Age"],
    language: "English",
    reviews: [ { user: 1, text: "One of the best..." },
               { user: 2, text: "It's hard to..." } ]
}
```

Notes:

Array of Documents

```
{   _id: 1,
    title: "The Great Gatsby",
    slug: "9781857150193-the-great-gatsby",
    author: 1,
    available: true,
    isbn: "9781857150193",
    pages: 176,
    publisher: {
        name: "Everyman's Library",
        date: ISODate("1991-09-19T00:00:00Z"),
        city: "London"
    },
    subjects: ["Love stories", "1920s", "Jazz Age"],
    language: "English",
    reviews: [ { user: 1, text: "One of the best..." },
```

```
                { user: 2, text: "It's hard to..." } ]
}
```

Notes:

Exercise: Users and Book Reviews

Design a schema for users and their book reviews. Usernames are immutable.

- Users
  - username (string)
  - email (string)
- Reviews
  - text (string)
  - rating (integer)
  - created_at (date)

Notes:

Solution A: Users and Book Reviews

Reviews may be queried by user or book

```
// db.users (one document per user)
{
     _id: ObjectId("..."),
    username: "bob",
    email: "bob@example.com"
}

// db.reviews (one document per review)
{
    _id: ObjectId("..."),
    user: ObjectId("..."),
    book: ObjectId("..."),
    rating: 5,
    text: "This book is excellent!",
    created_at: ISODate("2012-10-10T21:14:07.096Z")
}
```

Notes:

Solution B: Users and Book Reviews

Optimized to retrieve reviews by user

```
// db.users, one document per user with all reviews
{
    _id: ObjectId("..."),
    username: "bob",
    email: "bob@example.com",
    reviews: [
        {   book: ObjectId("..."),
            rating: 5,
            text: "This book is excellent!",
            created_at: ISODate("2012-10-10T21:14:07.096Z")
        }
    ]
}
```

Notes:

Solution C: Users and Book Reviews

Optimized to retrieve reviews by book

```
// db.users (one document per user)
{   _id: ObjectId("..."),
    username: "bob",
    email: "bob@example.com"
}

// db.books, one document per book with all reviews
{   _id: ObjectId("..."),
    // Other book fields...
    reviews: [ {   user: ObjectId("..."),
                   rating: 5,
                   text: "This book is excellent!",
                   created_at: ISODate("2014-11-10T21:14:07.096Z") } ]
}
```

Notes:

5.2 Schema Evolution

Learning Objectives

Upon completing this module, students should understand the basic philosophy of evolving a MongoDB schema during an application's lifetime:

- Development Phase
- Production Phase
- Iterative Modifications

Notes:

Development Phase

Support basic CRUD functionality:

- Inserts for authors and books
- Find authors by name
- Find books by basics of title, subject, etc.

Notes:

Development Phase: Known Query Patterns

```
// Find authors by last name.
db.authors.ensureIndex({ "lastName": 1 })

// Find books by slug for detail view
db.books.ensureIndex({ "slug": 1 })

// Find books by subject (multi-key)
db.books.ensureIndex({ "subjects": 1 })

// Find books by publisher (index on embedded doc)
db.books.ensureIndex({ "publisher.name": 1 })
```

Notes:

Production Phase

Evolve the schema to meet the application's read and write patterns.

Notes:

Production Phase: Read Patterns

List books by author last name

```
authors = db.authors.find({ lastName: /^f.*/i }, { _id: 1 });

authorIds = authors.map(function(x) { return x._id; });

db.books.find({author: { $in: authorIds }});
```

Notes:

Addressing List Books by Last Name

"Cache" the author name in an embedded document.

```
{
    _id: 1,
    title: "The Great Gatsby",
    author: {
        firstName: "F. Scott",
        lastName: "Fitzgerald"
    }
    // Other fields follow...
}
```

Queries are now one step

```
db.books.find({ "author.firstName": /^f.*/i })
```

Notes:

Production Phase: Write Patterns

Users can review a book.

```
review = {
    user: 1,
    text: "I thought this book was great!",
    rating: 5
};

db.books.update(
    { _id: 3 },
    { $push: { reviews: review }}
);
```

Caveats:

- Document size limit (16MB)
- Storage fragmentation after many updates/deletes

Notes:

Exercise: Recent Reviews

- Display the 10 most recent reviews by a user.
- Make efficient use of memory and disk seeks.

Notes:

Solution: Recent Reviews, Schema

Store users' reviews in monthly buckets.

```
// db.reviews (one document per user per month)
{   _id: "bob-201412",
    reviews: [
        {   _id: ObjectId("..."),
            rating: 5,
            text: "This book is excellent!",
            created_at: ISODate("2014-12-10T21:14:07.096Z")
        },
        {   _id: ObjectId("..."),
            rating: 2,
            text: "I didn't really enjoy this book.",
            created_at: ISODate("2014-12-11T20:12:50.594Z")
        }
```

```
    ]
}
```

Notes:

Solution: Recent Reviews, Update

Adding a new review to the appropriate bucket

```
myReview = {
    _id: ObjectId("..."),
    rating: 3,
    text: "An average read.",
    created_at: ISODate("2012-10-13T12:26:11.502Z")
};

db.reviews.update(
      { _id: "bob-201210" },
      { $push: { reviews: myReview }}
);
```

Notes:

Solution: Recent Reviews, Read

Display the 10 most recent reviews by a user

```
cursor = db.reviews.find(
    { _id: /^bob-/ },
    { reviews: { $slice: -10 }}
).sort({ _id: -1 }).batchSize(5);

num = 0;

while (cursor.hasNext() &amp;&amp; num &lt; 10) {
    doc = cursor.next();

    for (var i = 0; i &lt; doc.reviews.length &amp;&amp; num &lt; 10; ++i, ++num) {
        printjson(doc.reviews[i]);
    }
}
```

Notes:

Solution: Recent Reviews, Delete

Deleting a review

```
cursor = db.reviews.update(
    { _id: "bob-201210" },
    { $pull: { reviews: { _id: ObjectId("...") }}}
);
```

Notes:

5.3 Common Schema Design Patterns

Learning Objectives

Upon completing this module students should understand common design patterns for modeling:

- 1-1 Relationships
- 1-M Relationships
- M-M Relationships
- Tree Structures

Notes:

1-1 Relationship

Let's pretend that authors only write one book.

Notes:

1-1: Linking

Either side, or both, can track the relationship.

```
db.books.findOne()
{
    _id: 1,
    title: "The Great Gatsby",
    slug: "9781857150193-the-great-gatsby",
    author: 1,
    // Other fields follow...
}

db.authors.findOne({ _id: 1 })
{
    _id: 1,
    firstName: "F. Scott",
    lastName: "Fitzgerald"
    book: 1,
}
```

Notes:

1-1: Embedding

```
db.books.findOne()
{
    _id: 1,
    title: "The Great Gatsby",
    slug: "9781857150193-the-great-gatsby",
    author: {
        firstName: "F. Scott",
        lastName: "Fitzgerald"
    }
    // Other fields follow...
}
```

Notes:

1-M Relationship

In reality, authors may write multiple books.

Notes:

1-M: Array of IDs

The "one" side tracks the relationship.

- Flexible and space-efficient
- Additional query needed for non-ID lookups

```
db.authors.findOne()
{
    _id: 1,
    firstName: "F. Scott",
    lastName: "Fitzgerald",
    books: [1, 3, 20]
}
```

Notes:

1-M: Single Field with ID

The "many" side tracks the relationship.

```
db.books.find({ author: 1 })
{
    _id: 1,
    title: "The Great Gatsby",
    slug: "9781857150193-the-great-gatsby",
    author: 1,
    // Other fields follow...
}

{
    _id: 3,
    title: "This Side of Paradise",
    slug: "9780679447238-this-side-of-paradise",
    author: 1,
    // Other fields follow...
}
```

Notes:

1-M: Array of Documents

```
db.authors.findOne()
{
    _id: 1,
    firstName: "F. Scott",
    lastName: "Fitzgerald",
    books: [
        { _id: 1, title: "The Great Gatsby" },
        { _id: 3, title: "This Side of Paradise" }
    ]
    // Other fields follow...
}
```

Notes:

M-M Relationship

Some books may also have co-authors.

Notes:

M-M: Array of IDs on Both Sides

```
db.books.findOne()
{
    _id: 1,
    title: "The Great Gatsby",
    authors: [1, 5]
    // Other fields follow...
}

db.authors.findOne()
{
    _id: 1,
    firstName: "F. Scott",
    lastName: "Fitzgerald",
    books: [1, 3, 20]
}
```

Notes:

M-M: Array of IDs on Both Sides

Query for all books by a given author.

```
db.books.find({ authors: 1 });
```

Query for all authors of a given book

```
db.authors.find({ books: 1 });
```

Notes:

M-M: Array of IDs on One Side

```
db.books.findOne()
{
    _id: 1,
    title: "The Great Gatsby",
    authors: [1, 5]
    // Other fields follow...
}

db.authors.find({ _id: { $in: [1, 5] }})
{
    _id: 1,
    firstName: "F. Scott",
    lastName: "Fitzgerald"
}

{
    _id: 5,
    firstName: "Unknown",
    lastName: "Co-author"
}
```

Notes:

M-M: Array of IDs on One Side

Query for all books by a given author

```
db.books.find({ authors: 1 });
```

Query for all authors of a given book

```
book = db.books.findOne(
    { title: "The Great Gatsby" },
    { authors: 1 }
);

db.authors.find({ _id: { $in: book.authors }});
```

Notes:

Tree Structures

E.g., modeling a subject hierarchy.

Notes:

Allow users to browse by subject

```
db.subjects.findOne()
{
    _id: 1,
    name: "American Literature",
    sub_category: {
         name: "1920s",
         sub_category: { name: "Jazz Age" }
   }
}
```

- How can you search this collection?
- Be aware of document size limitations
- Benefit from hierarchy being in same document

Notes:

Alternative: Parents and Ancestors

```
db.subjects.find()
{   _id: "American Literature" }

{   _id : "1920s",
    ancestors: ["American Literature"],
    parent: "American Literature"
}

{   _id: "Jazz Age",
    ancestors: ["American Literature", "1920s"],
    parent: "1920s"
}

{   _id: "Jazz Age in New York",
    ancestors: ["American Literature", "1920s", "Jazz Age"],
    parent: "Jazz Age"
}
```

Notes:

Find Sub-Categories

```
db.subjects.find({ ancestors: "1920s" })
{
    _id: "Jazz Age",
    ancestors: ["American Literature", "1920s"],
    parent: "1920s"
}

{
    _id: "Jazz Age in New York",
    ancestors: ["American Literature", "1920s", "Jazz Age"],
    parent: "Jazz Age"
}
```

Notes:

Summary

- Schema design is different in MongoDB.
- Basic data design principles apply.
- It's about your application.
- It's about your data and how it's used.
- It's about the entire lifetime of your application.

Notes:

6 Replica Sets

6.1 Introduction to Replica Sets

Learning Objectives

Upon completing this module, students should understand:

- Striking the right balance between cost and redundancy
- The many scenarios replication addresses and why
- How to avoid downtime and data loss using replication

Notes:

Use Cases for Replication

- High Availability
- Disaster Recovery
- Functional Segregation

Notes:

High Availability (HA)

- Data still available following:
  - Equipment failure (e.g. server, network switch)
  - Datacenter failure
- This is achieved through automatic failover.

Notes:

Disaster Recovery (DR)

- We can duplicate data across:
  - Multiple database servers
  - Storage backends
  - Datacenters
- Can restore data from another node following:
  - Hardware failure
  - Service interruption

Notes:

Functional Segregation

There are opportunities to exploit the topology of a replica set.

- Based on physical location (e.g. rack or datacenter location)
- For analytics, reporting, data discovery, system tasks, etc.
- For backups

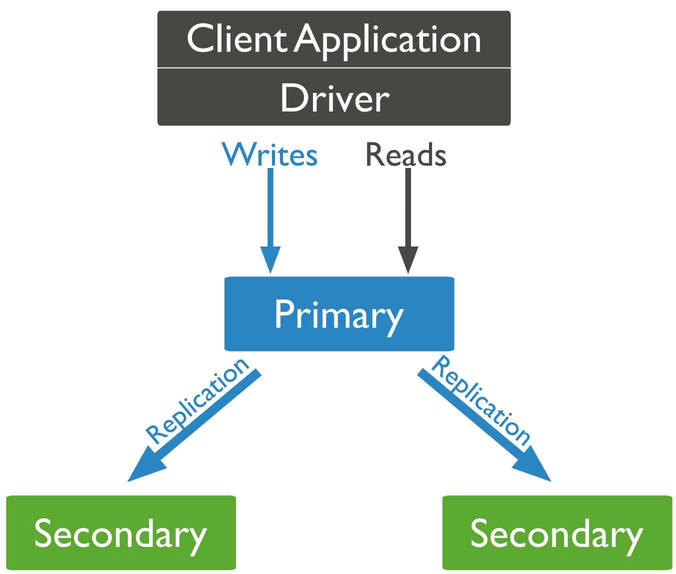
Notes:

Replication is Not Designed for Scaling

- Can be used for scaling reads, but generally not recommended.
- Drawbacks include:
  - Eventual consistency
  - Not scaling writes
  - Potential system overload when secondaries are unavailable
- Consider sharding for scaling reads and writes.

Notes:

Replica Sets



Notes:

Primary Server

- Clients send writes the primary only.
- MongoDB, Inc. maintains client drivers in many programming languages like Java, C#, Python, Ruby, and PHP.
- MongoDB drivers are replica set aware.

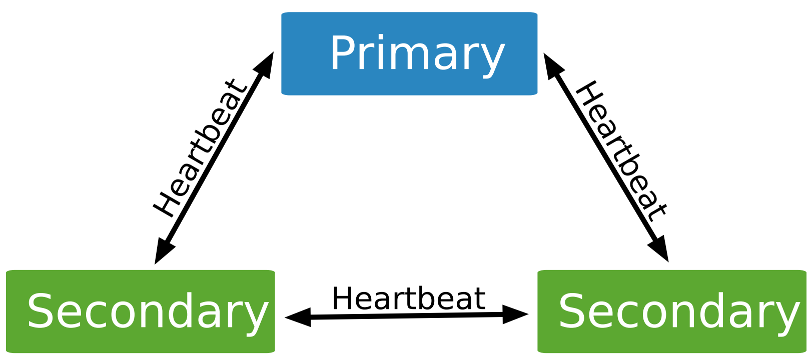
Notes:

Secondaries

- A secondary replicates operations from another node in the replica set.
- Secondaries usually replicate from the primary.
- Secondaries may also replicate from other secondaries. This is called replication chaining.
- A secondary may become primary as a result of a failover scenario.

Notes:

Heartbeats



Notes:

The Oplog

- The operations log, or oplog, is a special capped collection that is the basis for replication.
- The oplog maintains one entry for each document affected by every write operation.
- Secondaries copy operations from the oplog of their sync source.

Notes:

6.2 Write Concern

Learning Objectives

Upon completing this module students should understand:

- How and when rollback occurs in MongoDB.
- The tradeoffs between durability and performance.
- Write concern as a means of ensuring durability in MongoDB.
- The different levels of write concern.

Notes:

What happens to the write?

- A write is sent to a primary.
- The primary acknowledges the write to the client.
- And then the primary becomes unavailable before a secondary can replicate the write

Notes:

Answer

- Another member might be elected primary.
- It will not have the last write that occurred before the previous primary became unavailable.
- When the previous primary becomes available again:
  - It will note it has writes that were not replicated.
  - It will put these writes into a `rollback file`.
  - A human will need to determine what to do with this data.
- This is default behavior in MongoDB and can be controlled using `write concern`.

Notes:

Balancing Durability with Performance

- The previous scenario is a specific instance of a common distributed systems problem.
- For some applications it might be acceptable for writes to be rolled back.
- Other applications may have varying requirements with regard to durability.
- Tunable write concern:
  - Make critical operations persist to an entire MongoDB deployment.
  - Specify replication to fewer nodes for less important operations.

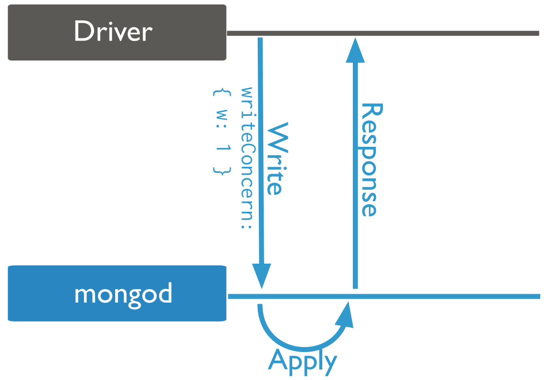
Notes:

Defining Write Concern

- Clients may define the write concern per write operation, if necessary.
- Standardize on specific levels of write concerns for different classes of writes.
- In the discussion that follows we will look at increasingly strict levels of write concern.

Notes:

Write Concern: `{ w : 1 }`



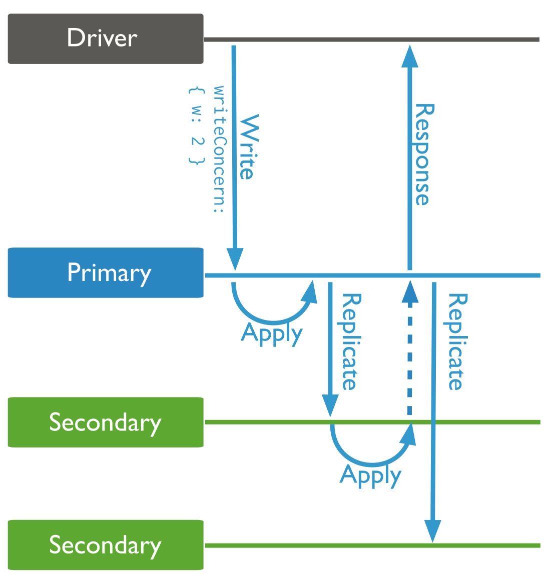
Notes:

Example: `{ w : 1 }`

```
db.edges.insert({ from : "tom185", to : "mary_p" }, { w : 1 })
```

Notes:

Write Concern: `{ w : 2 }`



Notes:

Example: `{ w : 2 }`

```
db.customer.update({ user : "mary_p" },
                   { $push : { shoppingCart:
                     { _id : 335443, name : "Brew-a-cup",
                       price : 45.79 } } },
                   { w : 2 })
```

Notes:

Other Write Concerns

- You may specify any integer as the value of the `w` field for write concern.
- This guarantees that write operations have propagated to the specified number of members.
- E.g., `{ w : 3 }`, `{ w : 4}`, etc.

Notes:

Write Concern: `{ w : "majority" }`

- Ensures the primary completed the write (in RAM).
- Ensures write operations have propagated to a majority of a replica set's members.
- Avoids hard coding assumptions about the size of your replica set into your application.
- Using majority trades off performance for durability.
- It is suitable for critical writes and to avoid rollbacks.

Notes:

Example: { w : "majority" }

```
db.products.update({ _id : 335443 },
                   { $inc : { inStock : -1 } },
                   { w : "majority" })
```

Notes:

Quiz: Which write concern?

Suppose you have a replica set with 7 data nodes. Your application has critical inserts for which you do not want rollbacks to happen. Secondaries may be taken down from to time for maintenance, leaving you with a potential 4 server replica set. Which write concern is best suited for these critical inserts?

- { w : 1 }
- { w : 2 }
- { w : 3 }
- { w : 4 }
- { w : "majority" }

Notes:

Further Reading

See Write Concern Reference[8] for more details on write concern configurations, including setting timeouts and identifying specific replica set members that must acknowledge writes (i.e. tag sets[9]).

[8] http://docs.mongodb.org/manual/reference/write-concern

[9] http://docs.mongodb.org/manual/tutorial/configure-replica-set-tag-sets/#replica-set-configuration-tag-sets

6.3 Read Preference

What is Read Preference?

- Read preference allows you to specify the nodes in a replica set to read from.
- Clients only read from the primary by default.
- There are some situations in which a client may want to read from:
  - Any secondary
  - A specific secondary
  - A specific type of secondary
- Only read from a secondary if you can tolerate possibly stale data, as not all writes might have replicated.

Notes:

Use Cases

- Running systems operations without affecting the front-end application.
- Providing local reads for geographically distributed applications.
- Maintaining availability during a failover.

Notes:

Not for Scaling

- In general, do *not* read from secondaries to provide extra capacity for reads.
- Sharding[10] increases read and write capacity by distributing operations across a group of machines.
- Sharding is a better strategy for adding capacity.

Notes:

[10] http://docs.mongodb.org/manual/sharding

Read Preference Modes

MongoDB drivers support the following read preferences. Note that `hidden` nodes will never be read from when connected via the replica set.

- **primary**: Default. All operations read from the primary.
- **primaryPreferred**: Read from the primary but if it is unavailable, read from secondary members.
- **secondary**: All operations read from the secondary members of the replica set.
- **secondaryPreferred**: Read from secondary members but if no secondaries are available, read from the primary.
- **nearest**: Read from member of the replica set with the least network latency, regardless of the member's type.

Notes:

Tag Sets

- There is also the option to used tag sets.
- You may tag nodes such that queries that contain the tag will be routed to one of the servers with that tag.
- This can be useful for running reports, say for a particular data center or nodes with different hardware (e.g. hard disks vs SSDs).

For example, in the mongo shell:

```
conf = rs.conf()
conf.members[0].tags = { dc : "east", use : "production" }
conf.members[1].tags = { dc : "east", use : "reporting" }
conf.members[2].tags = { use : "production" }
rs.reconfig(conf)
```

Notes:

7 Sharding

7.1 Introduction to Sharding

Learning Objectives

Upon completing this module, students should understand:

- What problems sharding solves
- When sharding is appropriate
- The importance of the shard key and how to choose a good one
- Why sharding increases the need for redundancy

Notes:

Contrast with Replication

- In an earlier module, we discussed Replication.
- This should never be confused with sharding.
- Replication is about high availability and durability.
  - Taking your data and constantly copying it
  - Being ready to have another machine step in to field requests.

Notes:

Sharding is Concerned with Scale

- What happens when a system is unable to handle the application load?
- It is time to consider scaling.
- There are 2 types of scaling we want to consider:
  - Vertical scaling
  - Horizontal scaling

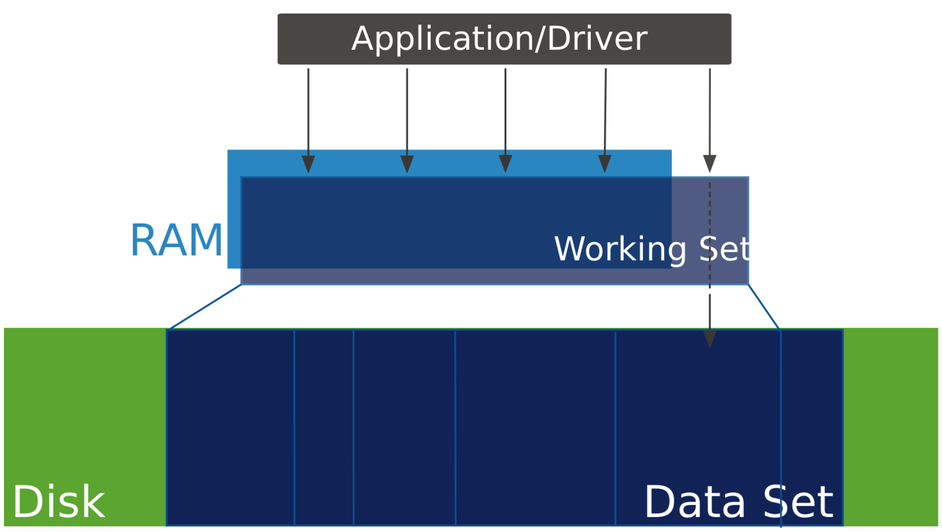
Notes:

Vertical Scaling

- Adding more RAM, faster disks, etc.
- When is this the solution?
- First, consider a concept called the `working set`.

Notes:

The Working Set



Notes:

Limitations of Vertical Scaling

- There is a limit to how much RAM one machine can support.
- There are other bottlenecks such as I/O, disk access and network.
- Cost may limit our ability to scale up.
- There may be requirements to have a large working set that no single machine could possible support.
- This is when it is time to scale horizontally.

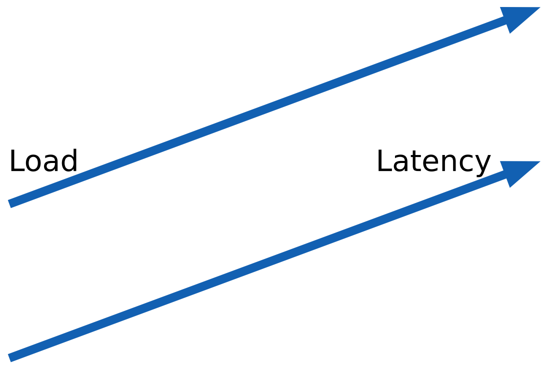
Notes:

Sharding Overview

- MongoDB enables you to scale horizontally through sharding.
- Sharding is about adding more capacity to your system.
- MongoDB's sharding solution is designed to perform well on commodity hardware.
- The details of sharding are abstracted away from applications.
- Queries are performed the same way as if sending operations to a single server.
- Connections work the same by default.

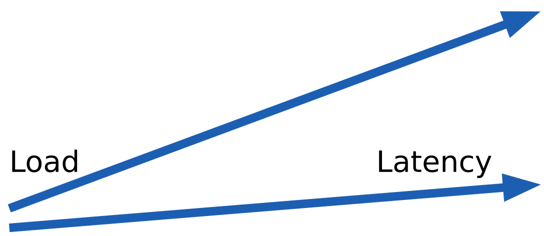
Notes:

A Model that Does Not Scale



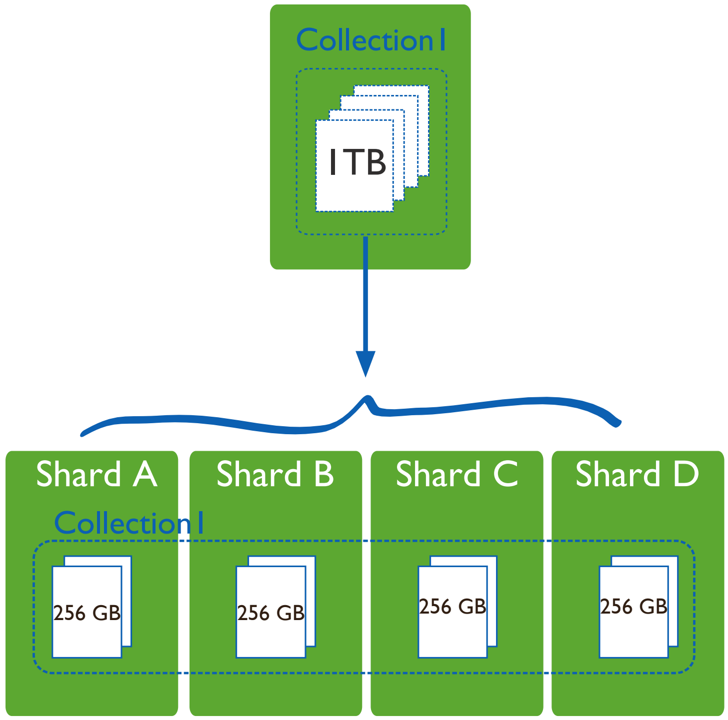
Notes:

A Scalable Model



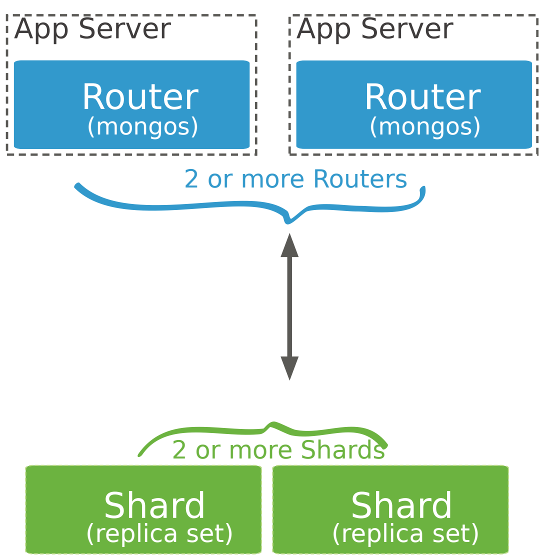
Notes:

Sharding Basics



Notes:

Sharded Cluster Architecture



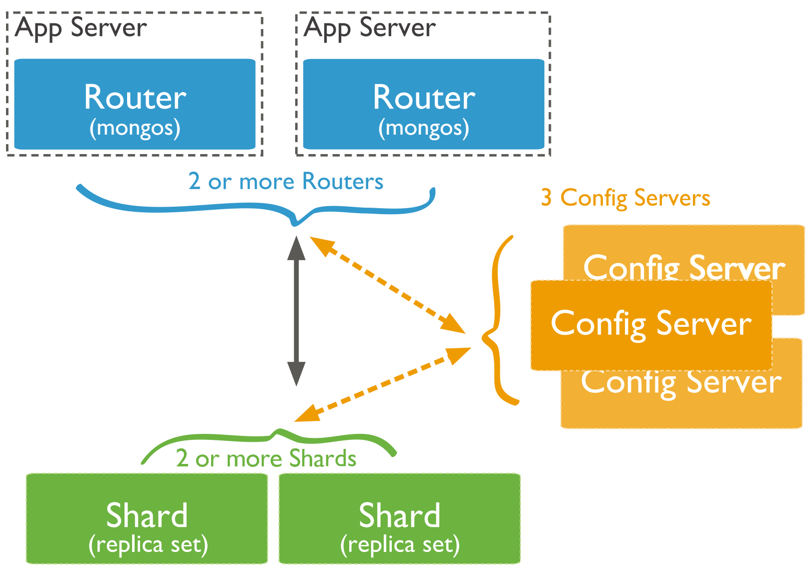
Notes:

Mongos

- A mongos is responsible for accepting requests and returning results to an application driver.
- In a sharded cluster, nearly all operations go through a mongos.
- A sharded cluster can have as many mongos routers as required.
- It is typical for each application server to have one mongos.
- Always use more than one mongos to avoid a single point of failure.

Notes:

Config Servers



Notes:

Config Server Hardware Requirements

- Quality network interfaces
- A small amount of disk space (typically a few GB)
- A small amount of RAM (typically a few GB)
- The larger the sharded cluster, the greater the config server hardware requirements.

Notes:

When to Shard

- If you have more data than one machine can hold on its drives
- If your application is write heavy and you experiencing too much latency.
- If your working set outgrows the memory you can allocate to a single machine.

Notes:

Possible Imbalance?

- Depending on how you configure sharding, data can become unbalanced on your sharded cluster.
  - Some shards might receive more inserts than others.
  - Some shards might have documents that grow more than those in other shards.
- This may result in too much load on a single shard.
  - Reads and writes
  - Disk activity
- This would defeat the purpose of sharding.

Notes:

Balancing Shards

- MongoDB divides data into `chunks`.
- This is bookkeeping metadata.
  - There is nothing in a document that indicates its chunk.
  - The document does not need to be updated if its assigned chunk changes.
- If a chunk grows too large MongoDB will split it into two chunks.
- The MongoDB balancer keeps chunks distributed across shards in equal numbers.
- However, a balanced sharded cluster depends on a good shard key.

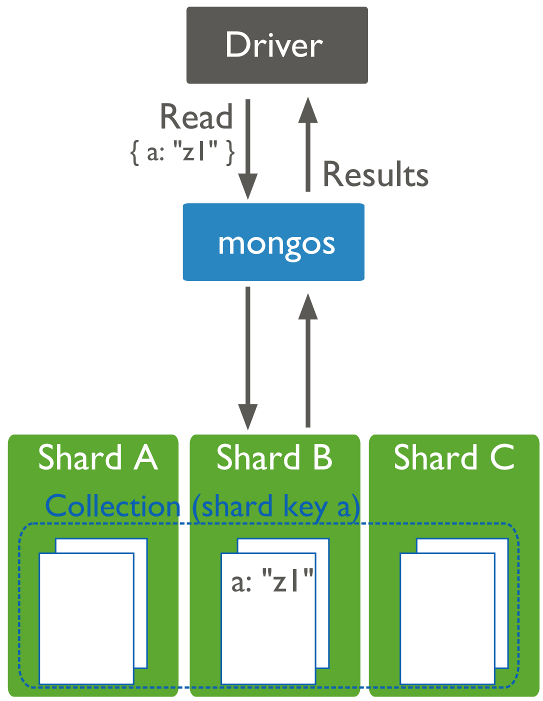
Notes:

What is a Shard Key?

- You must define a shard key for a sharded collection.
- Based on one or more fields that every document must contain.
- Is immutable.
- The shard key determines where documents are located in the cluster.
- It is used to route operations to the appropriate shard.
- For reads and writes

Notes:

Targeted Query Using Shard Key



Notes:

With a Good Shard Key

You might easily see that:

- Reads hit only 1 or 2 shards per query.
- Writes are distributed across all servers.
- Your disk usage is evenly distributed across shards.
- Things stay this way as you scale.

Notes:

With a Bad Shard Key

You might see that:

- Your reads hit every shard.
- Your writes are concentrated on one shard.
- Most of your data is on just a few shards.
- Adding more shards to the cluster will not help.

Notes:

Choosing a Shard Key

Generally, you want a shard key:

- That has high cardinality
- That is used in the majority of read queries
- For which the values read and write operations use are randomly distributed
- For which the majority or reads are routed to a particular server

Notes:

More Specifically

- Your shard key should be consistent with your query patterns.
- If reads usually find only one document, you only need good cardinality.
- If reads retrieve many documents:
  - Your shard key supports locality
  - Matching documents will reside on the same shard.

Notes:

Cardinality

- A good shard key will have high cardinality.
- A relatively small number of documents should have the same shard key.
- Otherwise operations become isolated to the same server.
- Because documents with the same shard key reside on the same shard.
- Adding more servers will not help.
- Hashing will not help.

Notes:

Non-Monotonic

- A good shard key will generate new values non-monotonically.
- Datetimes, counters, and ObjectIds make bad shard keys.
- Monotonic shard keys cause all inserts to happen on the same shard.
- Hashing will solve this problem.
- However, doing range queries with a hashed shard key will perform a scatter-gather query across the cluster.

Notes:

Shards Should be Replica Sets

- As the number of shards increases, the number of servers in your deployment increases.
- This increases the probability that one server will fail on any given day.
- With redundancy built into each shard you can mitigate this risk.

Notes:

8 Supplementary Material (Time Permitting)

8.1 Geospatial Indexes

Learning Objectives

Upon completing this module, students should understand:

- Use cases of geospatial indexes
- The two types of geospatial indexes
- How to create 2d geospatial indexes
- How to query for documents in a region
- How to create 2dsphere indexes
- Types of geoJSON objects
- How to query using 2dsphere indexes

Notes:

Introduction to Geospatial Indexes

We can use geospatial indexes to quickly determine geometric relationships:

- All points within a certain radius of another point.
- Whether or not points fall within a polygon
- Whether or not two polygons intersect

Notes:

Easiest to Start with 2 Dimensions

- Initially, it is easiest to think about geospatial indexes in two dimensions.
- And one type of geospatial index in MongoDB is a flat 2d index.
- With a geospatial index we can, for example, search for nearby items.
- This is the type of service that many phone apps provide when, say, searching for a nearby cafe.
- We might have a query location identified by an X in a 2d coordinate system.

Notes:

Location Field

- A geospatial index is based on a location field within documents in a collection.
- The structure of location values depends on the type of geospatial index.
- We will go into more detail on this in a few minutes.
- We can identify other documents in this collection with Xs in our 2d coordinate system.

Notes:

Find Nearby Documents

- A geospatial index enables us to efficiently query a collection based on geometric relationships between documents and the query.
- For example, we can quickly locate all documents within a certain radius of our query location.
- In this example, we've illustrated a `$near` query in a 2d geospatial index.

Notes:

Flat vs. Spherical Indexes

There are two types of geospatial indexes:

- Flat, made with a `2d` index
- Two-dimensional spherical, made with the `2dsphere` index
  - Takes into account the curvature of the earth.
  - Joins any two points using a geodesic or "great circle arc".
  - Deviates from flat geometry as you get further from the equator, and as your points get further apart.

Notes:

Flat Geospatial Index

- This is a Cartesian treatment of coordinate pairs.
- E.g., would NOT know that the shortest path from Canada to Siberia is over the North Pole (if units are degrees).
- Can be used to describe any flat surface.
- Recommended if:
  - You have legacy coordinate pairs (MongoDB 2.2 or earlier).
  - You do not plan to use geoJSON objects such as LineStrings or Polygons.
  - You are not going to use points far enough North or South to worry about the Earth's curvature.

Notes:

Spherical Geospatial Index

- Knows about the curvature of the Earth.
- If you want to plot the shortest path from the Klondike to Siberia, this will know to go over the North Pole.
- Uses geoJSON objects (Points, LineString, and Polygons).
- Coordinate pairs are converted into geoJSON Points.

Notes:

Creating a 2d Index

Creating a 2d index:

```
db.collection.ensureIndex(
 { field_name : "2d", <optional additional field> : <value> },
 { <optional options document> } )
```

Possible options key-value pairs:

- `min : <lower bound>`
- `max : <upper bound>`
- `bits : <bits of precision for geohash>`

Notes:

Exercise: Creating a 2d Index

Create a 2d index on the collection `testcol` with:

- A min value of -20
- A max value of 20
- 10 bits of precision
- The field indexed should be `xy`.

Notes:

Inserting Documents with a 2d Index

There are two accepted formats:

- Legacy coordinate pairs
- Document with the following fields specified:
  - `lng` (longitude)
  - `lat` (latitude)

Notes:

Exercise: Inserting Documents with 2d Fields

- Insert 2 documents into the 'twoD' collection.
- Assign 2d coordinate values to the `xy` field of each document.
- Longitude values should be -3 and 3 respectively.
- Latitude values should be 0 and 0.4 respectively.

Notes:

Querying Documents Using a 2d Index

- Use `$near` to retrieve documents close to a given point.
- Use `$geoWithin` to find documents with a shape contained entirely within the query shape.
- Use the following operators to specify a query shape:
  - `$box`
  - `$polygon`
  - `$center` (circle)

Notes:

Example: Find Based on 2d Coords

Write a query to find all documents in the testcol collection that have an xy field value that falls entirely within the circle with center at [-2.5, -0.5] and a radius of 3.

```
db.testcol.find( { xy : { $geoWithin : { $center : [ [ -2.5, -0.5 ], 3 ] } } }
```

Notes:

Creating a 2dsphere Index

You can index one or more 2dsphere fields in an index.

```
db.collection.ensureIndex( { <location field> : "2dsphere" } )
```

Notes:

The geoJSON Specification

- The geoJSON format encodes location data on the earth.
- The spec is at http://geojson.org/geojson-spec.html
- This spec is incorporated in MongoDB 2dsphere indexes.
- Includes Point, LineString, Polygon, and combinations of these.

Notes:

geoJSON Considerations

- The coordinates of points are given in degrees (latitude then longitude)
- The LineString that joins two points will always be a geodesic.
- Short lines (around a few hundred kilometers or less) will go about where you would expect them to.
- Polygons are made of a closed set of LineStrings.

Notes:

Simple Types of 2dsphere Objects

Point: A single point on the globe

```
{ <field_name> : { type : "Point",
                   coordinates : [ <longitude>, <latitude> ] } }
```

Notes: **LineString**: A geodesic line that is defined by its two end Points

```
{ <field_name> : { type : "LineString",
                   coordinates : [ [ <longitude 1>, <latitude 1> ],
                                   [ <longitude 2>, <latitude 2> ],
                                   ...,
                                   [ <longitude n>, <latitude n> ] ] } }
```

Notes:

Polygons

Simple Polygon:

```
{ <field_name> : { type : "Polygon",
                   coordinates : [ [ [ <Point1 coordinate pair> ],
                                     [ <Point2 coordinate pair> ],
                                     ...
                                     [ <Point1 coordinate pair again> ] ]
                 } }
```

Polygon with One Hole:

```
{ <field_name> : { type : "Polygon",
                   coordinates : [ [ <Points that define outer polygon> ],
                                   [ <Points that define inner polygon> ] ]
                 } }
```

Notes:

Other Types of 2dsphere Objects

- **MultiPoint**: One or more Points in one document
- **MultiLine**: One or more LineStrings in one document
- **MultiPolygon**: One or more Polygons in one document
- **GeometryCollection**: One or more geoJSON objects in one document

Notes:

Exercise: Inserting geoJSON Objects (1)

Create a coordinate pair for each the following airports. Create one variable per airport.

- LaGuardia (New York): 40.7772° N, 73.8726° W
- JFK (New York): 40.6397° N, 73.7789° W
- Newark (New York): 40.6925° N, 74.1686° W
- Heathrow (London): 52.4775° N, 0.4614° W
- Gatwick (London): 51.1481° N, 0.1903° W
- Stansted (London): 51.8850° N, 0.2350° E
- Luton (London): 51.9000° N, 0.4333° W

Notes:

Exercise: Inserting geoJSON Objects (2)

- Now let's make arrays of these.
- Put all the New York area airports into an array called `nyPorts`.
- Put all the London area airports into an array called `londonPorts`.
- Create a third array for flight numbers: "AA4453", "VA3333", "UA2440"

Notes:

Exercise: Inserting geoJSON Objects (3)

- Create documents for every possible New York to London flight.
- Include a `flightNumber` field for each flight.

Notes:

Exercise: Creating a 2dsphere Index

- Create two indexes on the collection `flights`.
- Make the first a compound index on the fields:
  - `origin`
  - `destination`
  - `flightNumber`
- Specify 2dsphere indexes on both `origin` and `destination`.
- Specify a simple index on `name`.
- Make the second index just a 2dsphere index on destination.

Notes:

Querying 2dsphere Objects

`$geoNear`: Finds all points, orders them by distance from a position.

```
{ <field name> : { $near : { $geometry : {
                                  type : "Point",
                                  coordinates : [ lng, lat ] },
                                  $maxDistance : <meters> } } } }
```

`$near`: Just like `$geoNear`, except in very edge cases; check the docs.

`$geoWithin`: Only returns documents with a location completely contained within the query.

`$geoIntersects`: Returns documents with their indexed field intersecting any part of the shape in the query.

Notes:

8.2 TTL Indexes

Learning Objectives

Upon completing this module students should understand:

- How to create a TTL index.
- When a TTL indexed document will get deleted.
- Limitations of TTL indexes.

Notes:

TTL Index Basics

- TTL is short for "Time To Live".
- This must index a field of type "Date" (including ISODate) or "Timestamp"
- Any Date field older than expireAfterSeconds will get deleted at some point

Notes:

Creating a TTL Index

Create with:

```
db.collection.ensureIndex( { field_name : 1 },
                           { expireAfterSeconds : some_number } )
```

Notes:

Exercise: Creating a TTL Index

Let's create a TTL index on the `ttl` collection that will delete documents older than 30 seconds. Write a script that will insert documents at a rate of one per second.

```
db.testcol.drop()
db.testcol.ensureIndex( { a : 1 }, { expireAfterSeconds : 30 } )

i = 0
while (true) {
    i += 1;
    db.testcol.insert( { a : ISODate(), b : i } );
    sleep(1000);  // Sleep for 1 second
}
```

Notes:

Exercise: Check the Collection

Then, leaving that window open, open up a new terminal and connect to the database with the mongo shell. This will allow us to verify the TTL behavior.

```
// look at the output and wait. After a ramp-up of up to a minute or so,
// count() will be reset to 30 once/minute.
while (true) {
    print(db.testcol.count());
    sleep(100);
}
```

Notes:

8.3 Text Indexes

Learning Objectives

Upon completing this module, students should understand:

- The purpose of a text index
- How to create text indexes
- How to search using text indexes
- How to rank search results by relevance score

Notes:

What is a Text Index?

- A text index is based on the tokens (words, etc.) used in string fields.
- MongoDB supports text search for a number of languages.
- Text indexes drop language-specific stop words (e.g. in English "the", "an", "a", "and", etc.)
- Text indexes use simple, language-specific suffix stemming (e.g., "running" to "run")

Notes:

Creating a Text Index

You create a text index a little bit differently than you create a standard index.

```
db.collection.ensureIndex( { <field name> : "text" } )
```

Notes:

Exercise: Creating a Text Index

Create a text index on the "dialog" field of the montyPython collection.

```
db.montyPython.ensureIndex( { dialog : "text" } )
```

Notes:

Text Indexes are Similar to Multikey Indexes

- Continuing our example, you can treat the `dialog` field as a multikey index.
- A multikey index with each of the words in `dialog` as values.
- You can query the field using the `$text` operator.

Notes:

Exercise: Inserting Texts

Let's add some documents to our montyPython collection.

```
db.montyPython.insert( [
{ _id : 1,
  dialog : "What is the air-speed velocity of an unladen swallow?" },
{ _id : 2,
  dialog : "What do you mean? An African or a European swallow?" },
{ _id : 3,
  dialog : "Huh? I... I don’t know that." },
{ _id : 45,
  dialog : "You're using coconuts!" },
{ _id : 55,
  dialog : "What? A swallow carrying a coconut?" } ] )
```

Notes:

Querying a Text Index

Next, let's query the collection. The syntax is:

```
db.collection.find( { $text : { $search : "query terms go here" } } )
```

Notes:

Exercise: Querying a Text Index

Using the text index, find all documents in the montyPython collection with the word "swallow" in it.

```
// Returns 3 documents.
db.montyPython.find( { $text : { $search : "swallow" } } )
```

Notes:

Exercise: Querying Using Two Words

- Find all documents in the montyPython collection with either the word 'coconut' or 'swallow'.
- By default MongoDB ORs query terms together.
- E.g., if you query on two words, results include documents using either word.

```
// Finds 4 documents, 3 of which contain only one of the two words.
db.montyPython.find( { $text : { $search : "coconut swallow" } } )
```

Notes:

Search for a Phrase

- To match an exact phrase, include search terms in quotes (escaped).
- The following query selects documents containing the phrase "coffee cake":

  ```
  db.montyPython.find( { $text: { $search: "\"European swallow\"" } } )
  ```

Notes:

Text Search Score

- The search algorithm assigns a relevance score to each search result.
- The score is generated by a vector ranking algorithm.
- The documents can be sorted by that score.

```
db.collection.find(
    { $text : { $search : "swallow coconut"} },
    { textScore: {$meta : "textScore" } }
).sort(
        { textScore: { $meta: "textScore" } }
) )
```

Notes:

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