What's New in MongoDB 3.2 Workshop

Release 3.2

MongoDB, Inc.

June 23, 2016

Contents

1 Introduction

1.1 Warm Up

Introductions

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

Note:

- Tell the students about yourself:
  - Your role
  - Prior experience

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?

Note:

- Ask students to go around the room and introduce themselves.
- Make sure the names match the roster of attendees.
- Ask about what roles the students play in their organization and note on attendance sheet.
- Ask what software stacks students are using.
  - With MongoDB and in general.
  - Note this informaton as well.

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?

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!"

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.

1.2 Lab: Installing and Configuring 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

Production Releases

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

- Windows
- OSX
- Linux
- Solaris

Installing MongoDB

- Visit https://docs.mongodb.com/manual/installation/.
- Please install the Enterprise version of MongoDB.
- Click on the appropriate link, such as “Install on Windows” or “Install on OS X” and follow the instructions.
- Versions:
  - 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.

Linux Setup

```
PATH=$PATH:<path to mongodb>/bin

sudo mkdir -p /data/db

sudo chmod -R 744 /data/db

sudo chown -R `whoami` /data/db
```

Note:

- You might want to add the MongoDB bin directory to your path, e.g.
- Once installed, create the MongoDB data directory.
- Make sure you have write permission on this directory.

If you are using Koding these are a few instructions you can follow:

- Download MongoDB tarbal and setup the environment

```
wget http://downloads.mongodb.org/linux/mongodb-linux-x86_64-ubuntu1204-3.2.1.tgz
tar xzvf mongodb-linux-x86_64-ubuntu1204-3.2.1.tgz
cd mongodb-linux-x86_64-ubuntu1204-3.2.1/bin
export PATH=`pwd`:$PATH
```

Install on Windows

- Download and run the .msi Windows installer from mongodb.org/downloads.
- By default, binaries will be placed in the following directory.

```
C:\Program Files\MongoDB\Server\<VERSION>\bin
```

- It is helpful to add the location of the MongoDB binaries to your path.
- To do this, from "System Properties" select "Advanced" then "Environment Variables"

Note: Can also install Windows as a service, but not recommended since we need multiple mongod processes for future exercises

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Create a Data Directory on Windows

- Ensure there is a directory for your MongoDB data files.
- The default location is `\data\db`.
- Create a data directory with a command such as the following.

```
md \data\db
```

Note: Optionally, talk about the –dbpath variable and specifying a different location for the data files

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Launch a `mongod`

Explore the `mongod` command.

```
<path to mongodb>/bin/mongod --help
```

Launch a `mongod` with the MMAPv1 storage engine:

```
<path to mongodb>/bin/mongod
```

Alternatively, launch with the WiredTiger storage engine.

```
<path to mongodb>/bin/mongod --storageEngine wiredTiger
```

Specify an alternate path for data files using the `--dbpath` option. (Make sure the directory already exists.) E.g.,

```
<path to mongodb>/bin/mongod --storageEngine wiredTiger
                             --dbpath /test/mongodb/data/wt
```

Note:

- Please verify that all students have successfully installed MongoDB.
- Please verify that all can successfully launch a mongod.

The MMAPv1 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.

Note: Files for a single database increase in size as follows:

- sample.0 is 64 MB
- sample.1 is 128 MB
- sample.2 is 256 MB, etc.
- This continues until sample.5, which is 2 GB
- All subsequent data files are also 2 GB.

The WiredTiger Data Directory

```
ls /data/db
```

- The mongod.lock file
  - Used in the same way as MMAPv1.
- Data files
  - Each collection and index stored in its own file.
  - Will fail to start if MMAPv1 files found

Import Exercise Data

```
unzip usb_drive.zip

cd usb_drive

mongoimport -d sample -c tweets twitter.json

mongoimport -d sample -c zips zips.json

mongoimport -d sample -c grades grades.json

cd dump

mongorestore -d sample city

mongorestore -d sample digg
```

Note: If there is an error importing data directly from a USB drive, please copy the sampledata.zip file to your local computer first.

Note: For local installs

- Import the data provided on the USB drive into the *sample* database.

For Koding environment

- Download *sample* data from:

```
wget https://www.dropbox.com/s/54xsjwq59zoq1fe/sample.tgz
```

Launch a Mongo Shell

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

```
mongo
```

Display available commands.

```
help
```

Note: On Koding environment do the following:

- Create a new *Terminal* and rename it to **Client**

Explore Databases

Display available databases.

```
show dbs
```

To use a particular database we can type the following.

```
use <database_name>
```

```
db
```

Note:

- This assigns the variable `db` to a connection object for the selected database.
- We can display the name of the database we are currently using by evaluating `db` in the mongo shell.
- Highlight the power of the Mongo shell here.
- It is a fully programmable JavaScript environment.
  - To demonstrate this you can use the following code block

```
for(i=0;i<10;i++){ print("this is line "+i)}
```

Exploring Collections

```
show collections

db.<COLLECTION>.help()

db.<COLLECTION>.find()
```

Note:

- Show the collections available in this database.
- Show methods on the collection with parameters and a brief explanation.
- Finally, we can query for the documents in a collection.

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.

2 CRUD

2.1 The 3.2 Mongo Shell CRUD API

Learning Objectives

Upon completing this module students should be able to:

- Outline mappings between the old CRUD API and the new
- Locate the MongoDB CRUD API spec in GitHub

New CRUD API

- With the release of MongoDB 3.0, the drivers were updated to support a new CRUD API.
- See the CRUD API Spec[1] for details.
- MongoDB 3.2 includes support for the new CRUD API in the mongo shell.
- They important differences are in the methods used for writes.

`insert()` Operations

- The new CRUD API provides two methods to replace `insert()`.
  - `insertOne()`
  - `insertMany()`
- These provide more useful return values.

[1] https://github.com/mongodb/specifications/tree/master/source/crud

`insertOne()`

- `insertOne()` accepts one document to insert.
- Returns a document containing the `_id` of the document inserted.
- We will look at `insertOne()` in more detail in another section.

`insertMany()`

- Use `insertMany()` to perform bulk inserts.
- It accepts an array of the documents to be inserted.
- It returns a document containing an array of the `_id` values for documents inserted.
- We will look at `insertMany()` in detail in the next section.

`remove()` Operations

- The CRUD API provides two methods to replace `remove()`
  - `deleteOne()`
  - `deleteMany()`
- `remove()` is prone to user error:
  - By default, all documents matching the filter are removed.
  - To remove just one, users must pass a second parameter.
- The new methods eliminate this problem.
- We will look at `deleteOne()` and `deleteMany()` in detail in the next section.

`update()` Operations

- The following methods replace `update()` in the new API.
  - `updateOne()`
  - `updateMany()`

Rationale

- The default for `update()` is to update just one document.
  - Pass an optional Boolean parameter to update many documents.
  - This is the opposite behavior of `remove()`.
  - It is a source of confusion.

Rationale, cont'd

- `update()` also makes it easy to accidentally overwrite a document.
  - If we fail to use an update operator such as `$set` or `$inc`.
  - `updateOne` and `updateMany` throw an exception on such calls.
- We will look at `updateOne()` and `updateMany()` in more detail in the next section.

Replacing Documents

- If you do want to overwrite a document, use `replaceOne()`.
- `replaceOne()` does not require the use of an update operator.
- We will look at `replaceOne()` in more detail in the next section.

`findAndModify()` Operations

- For some use cases it is important to return the document modified.
- In earlier versions of MongoDB, `findAndModify()` was the method of choice.
- `findAndModify()` is a complex, combining the functionality of three operations:
  - delete
  - replace
  - update (including upserts)

Simplifying `findAndModify()` Operations

- In MongoDB 3.2 the shell accommodates the functionality of `findAndModify()` with:
  - `findOneAndDelete()`
  - `findOneAndReplace()`
  - `findOneAndUpdate()`
- These methods enable you to get the value of a modified document.
- We will discuss all three methods in another section.

2.2 Creating and Deleting Documents

Learning Objectives

Upon completing this module students should understand:

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

Creating New Documents

- Create documents using `insertOne()` and `insertMany()`.
- For example:

```
// Specify the collection name
db.<COLLECTION>.insertOne( { "name" : "Mongo" } )

// For example
db.people.insertOne( { "name" : "Mongo" } )
```

Example: Inserting a Document

Experiment with the following commands.

```
use sample

db.movies.insertOne( { "title" : "Jaws" } )

db.movies.find()
```

Note:

- Make sure the students are performing the operations along with you.
- Some students will have trouble starting things up, so be helpful at this stage.

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.

Example: Assigning _ids

Experiment with the following commands.

```
db.movies.insertOne( { "_id" : "Jaws", "year" : 1975 } )
db.movies.find()
```

Note:

- Note that you can assign an _id to be of almost any type.
- It does not need to be an ObjectId.

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.

Example: Inserts will fail if...

```
// fails because _id can't have an array value
db.movies.insertOne( { "_id" : [ "Star Wars",
                                 "The Empire Strikes Back",
                                 "Return of the Jedi" ] } )

// succeeds
db.movies.insertOne( { "_id" : "Star Wars" } )

// fails because of duplicate id
db.movies.insertOne( { "_id" : "Star Wars" } )

// malformed document
db.movies.insertOne( { "Star Wars" } )
```

Note:

- The following will fail because it attempts to use an array as an _id.

  ```
  db.movies.insertOne( { "_id" : [ "Star Wars",
                                   "The Empire Strikes Back",
                                   "Return of the Jedi" ] } )
  ```

- The second insert with `_id : "Star Wars"` will fail because there is already a document with _id of "Star Wars" in the collection.
- The following will fail because it is a malformed document (i.e. no field name, just a value).

```
db.movies.insertOne( { "Star Wars" } )
```

`insertMany()`

- You may bulk insert using an array of documents.
- Use `insertMany()` instead of `insertOne()`

Note:

- In the case of an ordered bulk operation, every operation will be executed in the order they are added to the bulk operation.
- In the case of an unordered bulk operation however there is no guarantee what order the operations are executed.
- With an unordered bulk operation, the operations in the list may be reordered to increase performance.

Ordered `insertMany()`

- 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>.insertMany` is an ordered insert.
- See the next exercise for an example.

Example: Ordered `insertMany()`

Experiment with the following operation.

```
db.movies.insertMany( [ { "_id" : "Batman", "year" : 1989 },
                        { "_id" : "Home Alone", "year" : 1990 },
                        { "_id" : "Ghostbusters", "year" : 1984 },
                        { "_id" : "Ghostbusters", "year" : 1984 } ] )
db.movies.find()
```

Note:

- This example has a duplicate key error.
- Only the first 3 documents will be inserted.

Unordered `insertMany()`

- Pass `{ ordered : false }` to `insertMany()` to perform unordered inserts.
- If any given insert fails, MongoDB will still attempt all of the others.
- The inserts may be executed in a different order than you specified.
- 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.

Example: Unordered `insertMany()`

Experiment with the following insert.

```
db.movies.insertMany( [ { "_id" : "Jaws", "year" : 1975 },
                        { "_id" : "Titanic", "year" : 1997 },
                        { "_id" : "The Lion King", "year" : 1994 } ],
                        { ordered : false } )
db.movies.find()
```

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

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()
```

Deleting Documents

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

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

Using `deleteOne()`

- Delete a document from a collection using `deleteOne()`
- This command has one required parameter, a query document.
- The first document in the collection matching the query document will be deleted.

Using `deleteMany()`

- Delete multiple documents from a collection using `deleteMany()`.
- This command has one required parameter, a query document.
- All documents in the collection matching the query document will be deleted.
- Pass an empty document to delete all documents.

Example: Deleting Documents

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

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

db.testcol.deleteMany( { a : 1 } )  // Delete 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.deleteMany( { a : { $lt : 5 } } )  // Remove three more

db.testcol.deleteOne( { a : { $lt : 10 } } )  // Remove one more

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

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

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.

Note: Mention that `drop()` is more performant than `deleteMany()`.

Example: Dropping a Collection

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

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

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.

Example: Dropping a Database

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

2.3 Updating Documents

Learning Objectives

Upon completing this module students should understand

- The `replaceOne()` method
- The `updateOne()` method
- The `updateMany()` method
- The required parameters for these methods
- Field update operators
- Array update operators
- The concept of an upsert and use cases.
- The `findOneAndReplace()` and `findOneAndUpdate()` methods

The `replaceOne()` Method

- Takes one document and replaces it with another
  - But leaves the _id unchanged
- Takes two parameters:
  - A matching document
  - A replacement document
- This is, in some sense, the simplest form of update

Note:

- By "simplest," we mean that it's simple conceptually – that replacing a document is a sort of basic idea of how an update happens.
- We will later see update methods that will involve only changing some fields.

First Parameter to `replaceOne()`

- Required parameters for `replaceOne()`
  - The query parameter:
    - Use the same syntax as with `find()`
    - Only the first document found is replaced
- `replaceOne()` cannot delete a document

Second Parameter to `replaceOne()`

- The second parameter is the replacement parameter:
  - The document to replace the original document
- The _id must stay the same
- You must replace the entire document
  - You cannot modify just one field
  - Except for the _id

Note:

- If they try to modify the _id, it will throw an error

Example: `replaceOne()`

```
db.movies.insertOne( { title: "Batman" } )
db.movies.find()
db.movies.replaceOne( { title : "Batman" }, { imdb_rating : 7.7 } )
db.movies.find()
db.movies.replaceOne( { imdb_rating: 7.7 },
                      { title: "Batman", imdb_rating: 7.7 } )
db.movies.find()
db.movies.replaceOne( { }, { title: "Batman" } )
db.movies.find()  // back in original state
db.movies.replaceOne( { }, { _id : ObjectId() } )
```

Note:

- Ask the students why the first replace killed the `title` field
- Ask why the final replace failed

The `updateOne()` Method

- Mutate one document in MongoDB using `updateOne()`
  - Affects only the _first_ document found
- Two parameters:
  - A query document
    - same syntax as with `find()`
  - Change document
    - Operators specify the fields and changes

`$set` and `$unset`

- Use to specify fields to update for `UpdateOne()`
- If the field already exists, using `$set` will change its value
  - If not, `$set` will create it, set to the new value
- Only specified fields will change
- Alternatively, remove a field using `$unset`

Example (Setup)

```
db.movies.insertMany( [
  {
    "title" : "Batman",
    "category" : [ "action", "adventure" ],
    "imdb_rating" : 7.6,
    "budget" : 35
  },
  {
    "title" : "Godzilla",
    "category" : [ "action",
    "adventure", "sci-fi" ],
    "imdb_rating" : 6.6
  },
  {
    "title" : "Home Alone",
    "category" : [ "family", "comedy" ],
    "imdb_rating" : 7.4
  }
] )
```

Example: `$set` and `$unset`

```
db.movies.updateOne( { "title" : "Batman" },
                     { $set : { "imdb_rating" : 7.7 } } )
db.movies.updateOne( { "title" : "Godzilla" },
                     { $set : { "budget" : 1 } } )
db.movies.updateOne( { "title" : "Home Alone" },
                     { $set : { "budget" : 15,
                                "imdb_rating" : 5.5 } } )
db.movies.updateOne( { "title" : "Home Alone" },
                     { $unset :  { "budget" : 1 } } )
db.movies.find()
```

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`: Update one or more fields (already discussed).
- `$unset` Delete a field (already discussed).
- `$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.

Example: Update Operators

```
db.movies.updateOne( { title: "Batman" }, { $inc: { "imdb_rating" : 2 } } )
db.movies.updateOne( { title: "Home Alone" }, { $inc: { "budget" : 5 } } )
db.movies.updateOne( { title: "Batman" }, { $mul: { "imdb_rating" : 4 } } )
db.movies.updateOne( { title: "Batman" },
                     { $rename: { budget: "estimated_budget" } } )
db.movies.updateOne( { title: "Home Alone" }, { $min: { budget: 5 } } )
db.movies.updateOne( { title: "Home Alone" },
      { $currentDate : { last_updated: { $type: "timestamp" } } } )
// increment movie mentions by 10
db.movie_mentions.updateOne( { title: "E.T." },
      { $inc:  { "mentions_per_hour.5" : 10 } } )
```

The `updateMany()` Method

- Takes the same arguments as `updateOne`
- Updates all documents that match
  - `updateOne` stops after the first match
  - `updateMany` continues until it has matched all

Warning: Without an appropriate index, you may scan every document in the collection.

Example: `updateMany()`

```
// let's start tracking the number of sequals for each movie
db.movies.updateOne( { }, { $set : { "sequels" : 0 } } )
db.movies.find()
// we need updateMany to change all documents
db.movies.updateMany( { }, { $set : { "sequels" : 0 } } )
db.movies.find()
```

Array Element Updates by Index

- You can use dot notation to specify an array index
- You will update only that element
  - Other elements will not be affected

Example: Update Array Elements by Index

```
// add a sample document to track mentions per hour
db.movie_mentions.insertOne(
    { "title" : "E.T.",
      "day" : ISODate("2015-03-27T00:00:00.000Z"),
      "mentions_per_hour" : [ 0, 0, 0, 0, 0, 0, 0,
      0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
      0, 0 ]
    } )

// update all mentions for the fifth hour of the day
db.movie_mentions.updateOne(
    { "title" : "E.T." } ,
    { $set :  { "mentions_per_hour.5" : 2300 } } )
```

Note:

- Pattern for time series data
- Displaying charts is easy
  - Can change granularity to by the minute, hour, day, etc.

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.

Note:

- These operators may be applied to array fields.

Example: Array Operators

```
db.movies.updateOne(
    { "title" : "Batman" },
    { $push : { "category" : "superhero" } } )
db.movies.updateOne(
    { "title" : "Batman" },
    { $pushAll : { "category" : [ "villain", "comic-based" ] } } )
db.movies.updateOne(
    { "title" : "Batman" },
    { $pop : { "category" : 1 } } )
db.movies.updateOne(
    { "title" : "Batman" },
    { $pull : { "category" : "action" } } )
db.movies.updateOne(
    { "title" : "Batman" },
    { $pullAll : { "category" : [ "villain", "comic-based" ] } } )
```

Note:

- Pass $pop a value of -1 to remove the first element of an array and 1 to remove the last element in an array.

The Positional $ Operator

- $[2] 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>.updateOne(
    { <array> : value ... },
    { <update operator> : { "<array>.$" : value } }
)
```

Example: The Positional $ Operator

```
// the "action" category needs to be changed to "action-adventure"
db.movies.updateMany( { "category": "action",  },
                      { $set: { "category.$" : "action-adventure" } } )
```

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

Upserts

- If no document matches a write query:
  - By default, nothing happens
  - With `upsert: true`, inserts one new document
- Works for `updateOne()`, `updateMany()`, `replaceOne()`
- Syntax:

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

Upsert Mechanics

- Will update if documents matching the query exist
- Will insert if no documents match
  - Creates a new document using equality conditions in the query document
  - Adds an `_id` if the query did not specify one
  - Performs the write on the new document
- `updateMany()` will only create one document
  - If none match, of course

Example: Upserts

```
db.movies.updateOne( { "title" : "Jaws" },
                     { $inc: { "budget" : 5 } },
                     { upsert: true } )

db.movies.updateMany( { "title" : "Jaws II" },
                      { $inc: { "budget" : 5 } },
                      { upsert: true } )

db.movies.replaceOne( { "title" : "Jaws III", "category" : [ "horror" ] },
                      { $set : { "budget" : 1 } },
                      { upsert: true } )
```

Note:

- Note that an updateMany works just like updateOne when no matching documents are found.
- First query updates the document with “title” = “Jaws” by incrementing “budget”
- Second query: 1) creates a new document, 2) assigns an _id, 3) sets “title” to “Jaws II” 4) performs the update
- Third query: 1) creates a new document, 2) sets “title” : “Jaws III”, 3) Set budget to 1

`save()`

- The `db.<COLLECTION>.save()` method is syntactic sugar
  - Similar to `replaceOne()`, querying the `_id` field
  - Upsert if `_id` is not in the collection
- Syntax:

```
db.<COLLECTION>.save( <document> )
```

Example: `save()`

- If the document in the argument does not contain an `_id` field, then the `save()` method acts like `insertOne()` method
  - An ObjectId will be assigned to the `_id` field.
- If the document in the argument contains an `_id` field: then the `save()` method is equivalent to a replaceOne with the query argument on `_id` and the upsert option set to true

```
// insert
db.movies.save( { "title" : "Beverly Hills Cops", "imdb_rating" : 7.3 })

// update with { upsert: true }
db.movies.save( { "_id" : 1234, "title" : "Spider Man", "imdb_rating" : 7.3 })
```

Note:

- A lot of users prefer to use update/insert, to have more explicit control over the operation

---

Be careful with `save()`

Careful not to modify stale data when using `save()`. Example:

```
db.movies.drop()
db.movies.insertOne( { "title" : "Jaws", "imdb_rating" : 7.3 } )

db.movies.find( { "title" : "Jaws" } )

// store the complete document in the application
doc = db.movies.findOne( { "title" : "Jaws" } )

db.movies.updateOne( { "title" : "Jaws"  }, { $inc: { "imdb_rating" : 2 } } )
db.movies.find()

doc.imdb_rating = 7.4


db.movies.save(doc)  // just lost our incrementing of "imdb_rating"
db.movies.find()
```

`findOneAndUpdate()` and `findOneAndReplace()`

- Update (or replace) one document and return it
  - By default, the document is returned pre-write
- Can return the state before or after the update
- Makes a read plus a write atomic
- Can be used with upsert to insert a document

`findOneAndUpdate()` and `findOneAndReplace()` Options

- The following are optional fields for the options document
- `projection:` `<document>` - select the fields to see
- `sort:` `<document>` - sort to select the first document
- `maxTimeoutMS:` `<number>` - how long to wait
  - Returns an error, kills operation if exceeded
- `upsert:` `<boolean>` if true, performs an upsert

Example: `findOneAndUpdate()`

```
db.worker_queue.findOneAndUpdate(
    { state : "unprocessed" },
    { $set: { "worker_id" : 123, "state" : "processing" } },
    { upsert: true } )
```

`findOneAndDelete()`

- Not an update operation, but fits in with `findOneAnd` ...
- Returns the document and deletes it.
- Example:

```
db.foo.drop();
db.foo.insertMany( [ { a : 1 }, { a : 2 }, { a : 3 } ] );
db.foo.find();  // shows the documents.
db.foo.findOneAndDelete( { a : { $lte : 3 } } );
db.foo.find();
```

2.4 Lab: Updating Documents

Exercise: Pass Inspections

In the sample.inspections namespace, let's imagine that we want to do a little data cleaning. We've decided to eliminate the "Completed" inspection result and use only "No Violation Issued" for such inspection cases. Please update all inspections accordingly.

Note:

```
db.inspections.updateMany({result: "Completed"},
                          {$set: {result: "No Violation Issued"}})
{
  "acknowledged": true,
  "matchedCount": 20,
  "modifiedCount": 20
}
```

Exercise: Set `fine` value

For all inspections that failed, set a `fine` value of 100.

Note:

```
db.inspections.updateMany({result: "Fail"},
                          {$set: {fine: 100}})
{
  "acknowledged": true,
  "matchedCount": 1120,
  "modifiedCount": 1120
}
```

Exercise: Increase `fine` in ROSEDALE

- Update all inspections done in the city of "ROSEDALE".
- For failed inspections, raise the "fine" value by 150.

Note:

```
db.inspections.updateMany({"address.city": "ROSEDALE", result: "Fail" },
                          {$inc: {fine: 150}})
{
  "acknowledged": true,
  "matchedCount": 1120,
  "modifiedCount": 1120
}
```

Exercise: Give a pass to "MONGODB"

- Today MongoDB got a visit from the inspectors.
- We passed, of course.
- So go ahead and update "MongoDB" and set the `result` to "AWESOME"
- MongoDB's address is

```
{city: 'New York', zip: 10036, street: '43', number: 229}
```

Note:

```
db.inspections.updateOne({business_name: "MongoDB"},
                         {$set: {
                           address: {
                               city: "New York",
                               zip: 10036,
                               street: "43",
                               number: 229 },
                           result: "AWESOME",
                           id: "XXXXXXX",
                           certificate_number: 140021221},
                          $currentDate: {date: {$type: "date"}}},
                          {upsert: true})
{
        "acknowledged" : true,
        "matchedCount" : 0,
        "modifiedCount" : 0,
        "upsertedId" : ObjectId("573f29d8dc8e6b0ba6e8f594")
}
```

We can also add a variation to see if students can determine how to sort results so they can look at certificate numbers granted in sequence. Kudos to students that recognize the need to filter for certificate_number values that are integers and also do some form of projection.

```
db.inspections.find(
    {certificate_number: {$type:16}},
    {certificate_number: 1,
     id:1}).sort({certificate_number:-1}).limit(1)
```

Exercise: Updating Array Elements

Insert a document representing product metrics for a backpack:

```
db.product_metrics.insertOne(
   { name: "backpack",
     purchasesPast7Days: [ 0, 0, 0, 0, 0, 0, 0] })
```

Each 0 within the "purchasesPast7Days" field corresponds to a day of the week. The first element is Monday, the second element is Tuesday, etc.).

Write an update statement to increment the number of backpacks sold on Friday by 200.

Note:

- Talk about how this can be used for time series data, real-time graphs/charts

```
db.product_metrics.updateOne(
    {name: "backpack" },
    {$inc: { "purchases_past_7_days.4" : 200 } } )
```

3 Document Validation

3.1 Document Validation

Learning Objectives

Upon completing this module, students should be able to:

- Define the different types of document validation
- Distinguish use cases for document validation
- Create, discover, and bypass document validation in a collection
- List the restrictions on document validation

Introduction

- Prevents or warns when inserts/updates do not match schema constraints
- Can be implemented for a new or existing collection
- Can be bypassed, if necessary

Example

```
db.createCollection("products",
   {
      validator: {
          price : { $exists : true }
      },
      validationAction: "error"
   }
)
```

Note: validationAction: “error” means that the server will reject non-matching documents

Why Document Validation?

Consider the following use case:

- Several applications write to your data store
- Individual applications may validate their data
- You need to ensure validation across all clients

Why Document Validation? (Continued)

Another use case:

- You have changed your schema in order to improve performance
- You want to ensure that any write will also map the old schema to the new schema
- Document validation is a simple way of enforcing the new schema after migrating

`validationAction` and `validationLevel`

- Two settings control how document validation functions
- `validationLevel` – determines how strictly MongoDB applies validation rules
- `validationAction` – determines whether MongoDB should error or warn on invalid documents

Details

		validationLevel		
		off	moderate	strict
validationAction	warn	No checks	Warn on validation failure for inserts & updates to existing valid documents. Updates to existing invalid docs OK.	Warn on any validation failure for any insert or update.
	error	No checks	Reject invalid inserts & updates to existing valid documents. Updates to existing invalid docs OK.	Reject any violation of validation rules for any insert or update. **DEFAULT**

Quiz

- What are the uses for the two validationLevels?
- What are the uses for the two validationActions?

Note:

- After the next two slides, you can come back and review their answers

---

`validationLevel`: "strict"

- Useful when:
  - Creating a new collection
  - Validating writes to an existing collection already in compliance
  - Changing schema and updates should map documents to the new schema
- This will impose validation on update even to invalid documents

`validationLevel`: "moderate"

- Useful when:
  - Changing a schema and you have not migrated fully
  - Changing schema but the application can't map the old schema to the new in just one update

`validationAction`: "error"

- Useful when:
  - Your application will no longer support valid documents
  - Not all applications can be trusted to write valid documents
  - Invalid documents create regulatory compliance problems

`validationAction`: "warn"

- Useful when:
  - You need to receive all writes
  - Your application can handle multiple versions of the schema
  - Tracking schema-related issues is important

Note:

- You can compare their answers to what you've discussed in this slide and the previous ones

---

Creating a Collection with Document Validation

```
db.createCollection("products",
   {
      validator: {
          price: { $exists: true }
      },
      validationAction: "error"
   }
)
```

Note:

- This is the same example we saw at the beginning of this lesson

---

Seeing the Results of Validation

To see what the validation rules are for all collections in a database:

```
db.getCollectionInfos()
```

And you can see the results when you try to insert:

```
db.products.insertOne( { price: 25, currency: "USD" } )
```

Adding Validation to an Existing Collection

```
db.products.drop()
db.products.insertOne( { name: "watch", price: 10000, currency: "USD" } )
db.products.insertOne( { name: "happiness" } )
db.runCommand( {
   collMod: "products",
   validator: {
       price: { $exists: true }
   },
   validationAction: "error",
   validationLevel: "moderate"
} )
db.products.updateOne( { name : "happiness" }, { $set : { note: "Priceless." } } )
db.products.updateOne( { name : "watch" }, { $unset : { price : 1 } } )
db.products.insertOne( { name : "inner peace" } )
```

Note:

- First two inserts worked b/c there was no validation at first
- First update worked b/c the document didn't match before the update
- Second update failed because it doesn't match the validator and the document matched before the update was attempted
- Final insert failed because it didn't match the validator

Bypassing Document Validation

- You can bypass document validation using the `bypassDocumentValidation` option
- CRUD and aggregation methods support this option
- For deployments with access control enabled, this is subject to user roles restrictions
- See the MongoDB server documentation for details
- Security roles:
  - `dbAdmin` and `restore` can bypass validation
  - `bypassDocumentValidation` action can be set

Note:

- User roles are covered in the security section

Limits of Document Validation

- Document validation is not permitted for the following databases:
  - admin
  - local
  - config
- You cannot specify a validator for `system.*` collections

Note:

- Ask the students why you can't write to these databases.
  - It's because MongoDB holds metadata for security, replication, and sharding, respectively, in these databases.

Document Validation and Performance

- Validation adds an expression-matching evaluation to every insert and update
- Testing shows negligible impact on performance

Quiz

What are the validation levels available and what are the differences?

Note: Answers:

- Strict - every insert or update must pass validation
- Moderate:
  - Updates to invalid documents are permitted even if the update does not pass validation
  - New documents must be validated
  - Updates to valid documents must pass validation
- None - disables document validation

Quiz

What command do you use to determine what the validation rule is for the *things* collection?

Note:

- Trick question. You can find out for all collections in the database with db.getCollectionInfos(), but there's no way to do it for just one collection.

Quiz

On which three databases is document validation not permitted?

Note:

- admin: holds security
- local: holds the oplog and other replication information
- config: holds sharding metadata
- Your application should not write directly to these databases anyway

---

3.2 Lab: Document Validation

Exercise: Add validator to existing collection

- Import the `posts` collection (from posts.json) and look at a few documents to understand the schema.
- Insert the following document into the `posts` collection

```
{"Hi":"I'm not really a post, am I?"}
```

- Discuss: what are some restrictions on documents that a validator could and should enforce?
- Add a validator to the `posts` collection that enforces those restrictions
- Remove the previously inserted document and try inserting it again and see what happens

---

Note: Discuss the potential restrictions as a class, but have students write and add validators individually.

Some example restrictions:

- `body` is a string
- `permalink` matches a regex
- `date` is a date
- `author` is a string
- `title` is a string

An example of adding a validator to the `posts` collection:

```
db.runCommand( {
    "collMod": "posts",
    "validator": {
        "body": {"$type": "string"},
        "permalink": {"$regex": "^[A-z]{20}$"},
        "date": {"$type":"date"},
        "author": {"$type": "string"},
        "title": {"$type": "string"}
    }
})
```

Exercise: Create collection with validator

Create a collection `employees` with a validator that enforces the following restrictions on documents:

- The `name` field must exist and be a string
- The `salary` field must exist and be between 0 and 10,000 inclusive.
- The `email` field is optional but must be an email address in a valid format if present.
- The `phone` field is optional but must be a phone number in a valid format if present.
- At least one of the `email` and `phone` fields must be present.

Note:

- Examples on next slide.

Exercise: Create collection with validator (expected results)

```
// Valid documents
{"name":"Jane Smith", "salary":45, "email":"js@example.com"}
{"name":"Tim R. Jones", "salary":30,
 "phone":"234-555-6789","email":"trj@example.com"}
{"name":"Cedric E. Oxford", "salary":600, "phone":"918-555-1234"}

// Invalid documents
{"name":"Connor MacLeod", "salary":9001, "phone":"999-555-9999",
 "email":"thrcnbnly1"}
{"name":"Herman Hermit", "salary":9}
{"name":"Betsy Bedford", "salary":50, "phone":"", "email":"bb@example.com"}
```

Note: A possible solution could be the following:

```
db.createCollection("employees", {"validator":{
    "$and": [
        {
            "name": {"$type": "string"},
            "salary": {"$gte":0, "$lte":10000}
        },
        {"$or":[
            {"email":{"$exists": false}},
            {"email":{"$regex": /[A-z0-9_.+]+@[A-z0-9_.+]+\.com/}}
        ]},
        {"$or":[
            {"phone":{"$exists": false}},
            {"phone":{"$regex": /\(?[0-9]{3}\)?[- ]?[0-9]{3}[- ]?[0-9]{4}/}}
        ]},
        {"$or":[
            {"phone":{"$exists": true}},
            {"email":{"$exists": true}}
        ]}
    ]
}})
```

- Ensure that students can correctly implement the subtleties of the restrictions on the phone and email fields.
- Actual regular expressions for email addresses and phone numbers can be very complex, so less comprehensive approximations such as those above are acceptable.

```
// example of actual email validation regex
/(?:[a-z0-9!#$%&'*+/=?^_`{|}~-]+(?:\.[a-z0-9!#$%&'*+/=?^_`{|}~-]+)*|"(?:[\
x01-\x08\x0b\x0c\x0e-\x1f\x21\x23-\x5b\x5d-\x7f]|\\[\x01-\x09\x0b\x0c\x0e-
\x7f])*")@(?:(?:[a-z0-9](?:[a-z0-9-]*[a-z0-9])?\.)+[a-z0-9](?:[a-z0-9-]*[a
-z0-9])?|\[(?:(?:25[0-5]|2[0-4][0-9]|[01]?[0-9][0-9]?)\.){3}(?:25[0-5]|2[0
-4][0-9]|[01]?[0-9][0-9]?|[a-z0-9-]*[a-z0-9]:(?:[\x01-\x08\x0b\x0c\x0e-\x1
f\x21-\x5a\x53-\x7f]|\\[\x01-\x09\x0b\x0c\x0e-\x7f])+)\])/
// example of actual phone validation regex
/^(?:(?:\+?1\s*(?:[.-]\s*)?)?(?:\(\s*([2-9]1[02-9]|[2-9][02-8]1|[2-9][02-8
][02-9])\s*\)|([2-9]1[02-9]|[2-9][02-8]1|[2-9][02-8][02-9]))\s*(?:[.-]\s*)
?)?([2-9]1[02-9]|[2-9][02-9]1|[2-9][02-9]{2})\s*(?:[.-]\s*)?([0-9]{4})(?:\
s*(?:#|x\.?|ext\.?|extension)\s*(\d+))?$/
```

- Ensure that students successfully insert the valid example documents; they are needed in a later exercise.

Exercise: Change validator rules

Modify the validator for the `employees` collection to support the following additional restrictions:

- The `status` field must exist and must only be one of the following strings: "active", "on_vacation", "terminated"
- The `locked` field must exist and be a boolean

Note: Examples on next slide

Exercise: Change validator rules (expected results)

```
// Valid documents
{"name":"Jason Serivas", "salary":65, "email":"js@example.com",
 "status":"terminated", "locked":true}
{"name":"Logan Drizt", "salary":39,
 "phone":"234-555-6789","email":"ld@example.com", "status":"active",
 "locked":false}
{"name":"Mann Edger", "salary":100, "phone":"918-555-1234",
 "status":"on_vacation", "locked":false}

// Invalid documents
{"name":"Steven Cha", "salary":15, "email":"sc@example.com", "status":"alive",
 "locked":false}
{"name":"Julian Barriman", "salary":15, "email":"jb@example.com",
 "status":"on_vacation", "locked":"no"}
```

Note: A possible solution could be the following:

```
db.runCommand( {
    "collMod": "employees",
    "validator":{
        "$and": [
            {
                "name": {"$type": "string"},
                "salary": {"$gte":0, "$lte":10000},
                "status": {"$in": ["active","on_vacation","terminated"]},
                "locked": {"$type": "bool"}
            },
            {"$or":[
                {"email":{"$exists": false}},
                {"email":{"$regex":
                /(?:[a-z0-9!#$%&'*+/=?^_`{|}~-]+(?:\.[a-z0-9!#$%&'*+/=?^_`{|}~
                -]+)*|"(?:[\x01-\x08\x0b\x0c\x0e-\x1f\x21\x23-\x5b\x5d-\x7f]|\
                \[\x01-\x09\x0b\x0c\x0e-\x7f])*")@(?:(?:[a-z0-9](?:[a-z0-9-]*[
                a-z0-9])?\.)+[a-z0-9](?:[a-z0-9-]*[a-z0-9])?|\[(?:(?:25[0-5]|2
                [0-4][0-9]|[01]?[0-9][0-9]?)\.){3}(?:25[0-5]|2[0-4][0-9]|[01]?
                [0-9][0-9]?|[a-z0-9-]*[a-z0-9]:(?:[\x01-\x08\x0b\x0c\x0e-\x1f\
                x21-\x5a\x53-\x7f]|\\[\x01-\x09\x0b\x0c\x0e-\x7f])+)\])/}}
            ]},
            {"$or":[
                {"phone":{"$exists": false}},
                {"phone":{"$regex":
                /^(?:(?:\+?1\s*(?:[.-]\s*)?)?(?:\(\s*([2-9]1[02-9]|[2-9][02-8]
                1|[2-9][02-8][02-9])\s*\)|([2-9]1[02-9]|[2-9][02-8]1|[2-9][02-
                8][02-9]))\s*(?:[.-]\s*)?)?([2-9]1[02-9]|[2-9][02-9]1|[2-9][02
```

```
                -9]{2})\s*(?:[.-]\s*)?([0-9]{4})(?:\s*(?:#|x\.?|ext\.?|extensi
                on)\s*(\d+))?$/}}
            ]},
            {"$or":[
                {"phone":{"$exists": true}},
                {"email":{"$exists": true}}
            ]}
        ]
    }})
```

Exercise: Change validation level

Now that the `employees` validator has been updated, some of the already-inserted documents are not valid. This can be a problem when, for example, just updating an employee's salary.

- Try to update the salary of "Cedric E. Oxford". You should get a validation error.
- Now, change the validation level of the `employees` collection to allow updates of existing invalid documents, but still enforce validation of inserted documents and existing valid documents.

Note: Note that this permanently changes the validation level for all operations on the collection. Overriding the validation level on a per-operation basis is covered later.

You could ask the questions:

- When would this be required?
- What happens with updates?
- What happens with new inserts?

Example solution:

```
db.runCommand({"collMod":"employees", "validationLevel":"moderate"})
```

Exercise: Bypass validation

In some circumstances, it may be desirable to bypass validation to insert or update documents.

- Use the `bypassDocumentValidation` option to insert the document `{"hi":"there"}` into the `employees` collection
- Use the `bypassDocumentValidation` option to give all employees a salary of 999999.

Note: Example solutions:

```
db.runCommand({"insert":"employees","documents":[{"hi":"there"}],
               "bypassDocumentValidation":true})
db.runCommand({
    "update":"employees",
    "updates":[{
        "q":{},
        "u":{"$set":{"salary":999999}},
        "multi":true
    }],
    "bypassDocumentValidation":true})
```

- Students may ask, is it possible to bypass only part of the validation?
- No, there is no partial validation.

Exercise: Change validation action

In some cases, it may be desirable to simply log invalid actions, rather than prevent them.

- Change the validation action of the `employees` collection to reflect this behavior

---

Note: Example solution:

```
db.runCommand({"collMod":"employees", "validationAction":"warn"})
```

You could ask the questions:

- When would this be useful?

---

4 Partial Indexes

4.1 Partial Indexes

Learning Objectives

Upon completing this module, students should be able to:

- Outline how partial indexes work
- Distinguish partial indexes from sparse indexes
- List and describe the use cases for partial indexes
- Create and use partial indexes

What are Partial Indexes?

- Partial indexes only index the documents in a collection that match a filter expression.
- Benefits include:
  - Lower storage requirements
  - Reduced performance costs for index maintenance as writes occur

Creating Partial Indexes

- Create a partial index by:
  - Calling `db.collection.createIndex()`
  - Passing the `partialFilterExpression` option
- You can specify a `partialFilterExpression` on any MongoDB index type.
- The filter does not need to be on indexed fields, but it can be.

Example: Creating Partial Indexes

- Consider the following schema:

```
{ "_id" : 7, "integer" : 7, "importance" : "high" }
```

- Create a partial index on the “integer” field
- Create it only where “importance” is “high”

Example: Creating Partial Indexes (Continued)

```
db.integers.createIndex(
  { integer : 1 },
  { partialFilterExpression : { importance : "high" },
  name : "high_importance_integers" } )
```

Note:

- We are choosing to name this index; the name is optional
- This is a single-field index, but other index types work the same
- The filter can be on fields other than the index keys

Filter Conditions

- As the value for `partialFilterExpression`, specify a document that defines the filter.
- The following types of expressions are supported.
- Use these in combinations that are appropriate for your use case.
- Your filter may stipulate conditions on multiple fields.
  - equality expressions
  - `$exists`: true expression
  - `$gt`, `$gte`, `$lt`, `$lte` expressions
  - `$type` expressions
  - `$and` operator at the top-level only

Partial Indexes vs. Sparse Indexes

- Both sparse indexes and partial indexes include only a subset of documents in a collection.
- Sparse indexes reference only documents for which a specified field exists.
- The functionality of sparse indexes is subsumed by partial indexes.

```
db.integers.createIndex(
    { importance : 1 },
    { partialFilterExpression : { importance : { $exists : true } } }
    )  // creates the equivalent of a sparse index
```

Note:

- Using { $exists: true } is how to create sparse index functionality using a partial index
- Sparse indexes still work, but we now recommend people use partial indexes going forward

---

Quiz

Which documents in a collection will be referenced by a partial index on that collection?

Note:

- Correct answer: only those documents that match the `partialFilterExpression`
- Wrong answers:
  - All documents. This is the case for standard indexes.
  - Only those documents where the field exists. This is the case for sparse indexes.

Partial Indexes - Advantages

- Reduce storage requirements for indexes:
  - Disk
  - Memory
- Can reduce the performance impact of indexes on writes to a collection

Identifying Partial Indexes

```
> db.integers.getIndexes()
[
...,
  {
    "v" : 1,
    "key" : {
      "integer" : 1
    },
    "name" : "high_importance_integers",
    "ns" : "test.integers",
    "partialFilterExpression" : {
      "importance" : "high"
    }
  },
  ...
]
```

Note:

- You can identify a partial index from the output of getIndexes()
- The presence of of a partialFilterExpression indicates a partial index
- This also allows you to identify the coverage of the index
- This index is on the “integer” field
- But the partialFilterExpression is on the “importance” field
  - Only indexing the documents with “importance”: “high”

Partial Indexes Considerations

- Not used when:
  - The indexed field is not in the query
  - A query goes outside of the filter range, even if no documents are out of range
- You can .explain() queries to check them

Quiz

Consider the following partial index. Note the `partialFilterExpression` in particular:

```
{
  "v" : 1,
  "key" : {
    "score" : 1,
    "student_id" : 1
  },
  "name" : "score_1_student_id_1",
  "ns" : "test.scores",
  "partialFilterExpression" : {
    "score" : {
      "$gte" : 0.65
    },
    "subject_name" : "history"
  }
}
```

Quiz (Continued)

Which of the following documents are indexed?

```
{ "_id" : 1, "student_id" : 2, "score" : 0.84, "subject_name" : "history" }
{ "_id" : 2, "student_id" : 3, "score" : 0.57, "subject_name" : "history" }
{ "_id" : 3, "student_id" : 4, "score" : 0.56, "subject_name" : "physics" }
{ "_id" : 4, "student_id" : 4, "score" : 0.75, "subject_name" : "physics" }
{ "_id" : 5, "student_id" : 3, "score" : 0.89, "subject_name" : "history" }
```

Note:

- The first and last documents are the ones that will be indexed.

---

5 Aggregation

5.1 Aggregation in MongoDB 3.2

Learning Objectives

Upon completing this module, students will be able to:

- List and use the new aggregation stages in MongoDB 3.2
  - `$sample`
  - `$indexStats`
  - `$lookup`
- Use the new or revised operators in MongoDB 3.2

Sample Dataset

Mongoimport the `companies.json` file:

```
mongoimport -d training -c companies --drop companies.json
```

- You now have a dataset of companies on your server.
- We will use these for our examples.

New Pipeline Operators

- `$sample` used to pull in a random set of documents
- `$indexStats` shows how many hits the indexes get since the server process started
- `$lookup` enables you to do a left outer join across two collections

Introduction to `$sample`

- Randomized sample of documents
- Useful for calculating statistics
- `$sample` provides an efficient means of sampling a data set
- Though if the sample size requested is larger than 5% of the collection `$sample` will perform a collection scan
- Can use `$sample` only as a first stage of the pipeline

Example: `$sample`

```
db.companies.aggregate( [
     { $sample : { size : 5 } },
     { $project : { _id : 0, number_of_employees: 1 } }
] )
```

Note:

- Users will want their sample sizes to be large enough to be useful.
- 5 is too small for anything
- A statistician may be required for determining how much is enough; it depends on the distribution of data
- Currently, on WiredTiger, `$sample` can be quite slow. See: SERVER-23408[3].

Introduction to `$indexStats`

- Tells you how many times each index has been used since the server process began
- Must be the first stage of the pipeline
- You can use other stages to aggregate the data
- Returns one document per index
- The `accesses.ops` field reports the number of times an index was used

[3] https://jira.mongodb.org/browse/SERVER-23408

Example: `$indexStats`

Issue each of the following commands in the mongo shell, one at a time.

```
db.companies.dropIndexes()
db.companies.createIndex( { number_of_employees : 1 } )
db.companies.aggregate( [ { $indexStats: {} } ] )
db.companies.find( { number_of_employees : { $gte : 100 } },
                   { number_of_employees: 1 } ).next()
db.companies.find( { number_of_employees : { $gte : 100 } },
                   { number_of_employees: 1 } ).next()
db.companies.aggregate( [ { $indexStats: {} } ] )
```

Note:

- Point out the "accesses" doc, with ops, is 0 for the new index initially.
- Ops incremented to 2 from the two find() queries.
- The `.next()` operations are to get the DB to actually execute the query.
- _id did not increment because we weren't using the index
- Neither query changed its "since" field in the "accesses" doc
- If using replication, the oplog will query on _id when replicating.

Introduction to `$lookup`

- Pulls documents from a second collection into the pipeline
  - In SQL terms, performs a left outer join
  - The second collection must be in the same database
  - The second collection cannot be sharded
- Documents based on a matching field in each collection
- Previously, you could get this behavior with two separate queries
  - One to the collection that contains reference values
  - The other to the collection containing the documents referenced

Example: Using `$lookup`

Create a separate collection for `$lookup`

```
db.commentOnEmployees.insertMany( [
    { employeeCount: 405000,
      comment: "Biggest company in the set." },
    { employeeCount: 405000,
      comment: "So you get two comments." },
    { employeeCount: 100000,
      comment: "This is a suspiciously round number." },
    { employeeCount: 99999,
      comment: "This is a suspiciously accurate number." },
    { employeeCount: 99998,
      comment: "This isn't in the data set." }
    ] )
```

Example: Using `$lookup` (Continued)

```
db.companies.aggregate( [
  { $match: { number_of_employees: { $in:
      [ 405000, 388000, 100000, 99999, 99998 ] } } },
  { $project: { _id :0, name: 1, number_of_employees: 1 } },
  { $lookup: {
      from: "commentOnEmployees",
      localField: "number_of_employees",
      foreignField: "employeeCount",
      as: "example_comments"
  } },
  { $sort : { number_of_employees: -1 } } ] )
```

Reviewing the Output

- All companies matching the filter are included.
- Even if there is no corresponding comment (as for IBM)
- Note that the comment documents joined to each match are included in their entirety.
- Does not include documents in commentOnEmployees that don't match.

New Aggregation Functionality

3.2 introduced several new operators and expanded the functionality of a few operators:

- New accumulators for `$group`
- New arithmetic operators
- New array operators
- General enhancements

New Accumulators

- Used in the `$group` stage
- `$stdDevSamp` - sample standard deviation
- `$stdDevPop` - population standard deviation

```
db.companies.aggregate( [
{ $match : { number_of_employees: { $lt: 1000, $gte: 100 } } },
{ $group : {
    _id : null,
    mean_employees: { $avg : "$number_of_employees" },
    std_num_employees : { $stdDevPop: "$number_of_employees" } } }
] )
```

Note:

- The standard deviation of a population means you're looking at every member.
- The standard deviation of a sample means just a randomly selected subset of a larger population.
- It is not necessary to use the `$sample` stage.
- Don't go into the stats any deeper; this isn't a statistics class.

New Arithmetic Operators

- `$sqrt`: Calculate a square root
- `$abs`: Calculate the absolute value
- `$log`: Calculate the logarithm in a specified base
- `$log10`: Log base 10
- `$ln`: Natural logarithm

Note:

- All of these are well documented if they want to use them
- But there are too many to practice, so just go over them quick

---

New Arithmetic Operators (Continued)

- `$pow`: Raise a number to an exponent
- `$exp`: Raise e to a power
- `$trunc`: Truncate a number to its integer
- `$ceil`: Round up to an integer
- `$floor`: Round down to an integer

Example: `$trunc`

```
db.companies.aggregate( [
  { $match : { number_of_employees: { $gte: 100, $lt: 1000 } } },
  { $group : { _id : null,
               mean_employees: { $avg: "$number_of_employees" } } },
  { $project : { _id: 0,
                 truncated_mean_employees: { $trunc : "$mean_employees" } } }
   ] )
```

Note:

- We just selected one arithmetic operator to show
- They can go to the manual for syntax

New Array Operators

- `$slice`: returns a portion of an array
- `$arrayElemAt`: Returns an element at the index
- `$concatArrays`: Concatenates two or more arrays
- `$isArray`: Determines if the operand is an array or not
- `$filter`: Selects a subset of the array, based on the filter

Example: `$filter`

```
db.companies.aggregate( [
  { $match : { "funding_rounds.round_code": "e" } },
  { $project : {
      _id: 0, name: 1,
      series_e_funding: {
        $filter: {
          input: "$funding_rounds",
          as: "series_e_funding",
          cond: { $eq : [ "$$series_e_funding.round_code", "e" ] } } } } }
  }, {
    $project : {
      name: 1,
      "series_e_funding.raised_amount": 1,
      "series_e_funding.raised_currency_code": 1,
```

```
      "series_e_funding.year": 1 }
  } ] )
```

Note:

- Here we're filtering based on the round_code found in documents in the funding_rounds array.
- Just grabbing the subdocuments that match!
- Notice that the "cond" field of the `$filter` document requires an expression.
- The use of `$$` is because there's a variable, "series_e_funding", which we're creating in this stage of aggregation.
- It doesn't yet exist as a field, because the `$project` round isn't done, yet.

Changes to `$unwind` Behavior

- `$unwind` no longer errors on non-array operands.
- If the operand is not:
  - An array,
  - Missing
  - null
  - An empty array
- $unwind treats the operand as a single element array.

`$unwind` with a Document Operand

`$unwind` also supports this form:

```
{
  $unwind:
    {
      path: <field path>,
      includeArrayIndex: <string>,
      preserveNullAndEmptyArrays: <boolean>
    }
}
```

Document Operand Semantics

- `path` – field path to an array field
- `includeArrayIndex` – the name of a new field to hold the array index of the element (optional)
- `preserveNullAndEmptyArrays` – output a document only if `true` and the path is null, missing, or an empty array

Using Accumulators with `$project`

For array fields, the following accumulators can be used in the project stage starting in 3.2:

- `$avg`: Averages over values
- `$sum`: Sums the values
- `$min`: Finds the minimum value
- `$max`: finds the maximum value
- `$stdDevPop`, `$stdDevSamp`

Note: Unsupported accumulators:

- `$first`, `$last`
- `$push`
- `$addToSet`
- That's literally all of them

Example: `$project` Accumulators

```
db.foo.drop()
db.foo.insertMany( [ { numbers: [ 1, 2, 3, 4, 5 ] },
                     { numbers: [ 6, 7, 8, 9, 10 ] } ] )
db.foo.aggregate( [
  {
    $project: {
      _id: 0,
      avg: { $avg: "$numbers" },
      sum: { $sum: "$numbers" },
      min: { $min: "$numbers" },
      max: { $max: "$numbers" },
      stDevSamp: { $stdDevSamp: "$numbers" } }
  } ] )
db.foo.find( {}, { _id: 0 } )  // these are the original documents
```

Note:

- The example is simple enough that students can see everything
- One document out per document in

`$project`ing Arrays

You can now use `$project` to create arrays from existing non-array fields:

```
// $projecting arrays example
db.plants.drop()
db.plants.insertMany( [
  { _id: "yellow plants", fruit: "banana", vegetable: "squash" },
  { _id: "red plants", fruit: "strawberry", vegetable: "radish" } ] )
db.plants.aggregate( [ { $project: { plant_list: [ "$fruit", "$vegetable" ] } } ] )
```

5.2 Lab: 3.2 Aggregation

Data Set

We have a normalized data set of digg `users` and their corresponding `stories` linked by `user._id`

```
> db.users.findOne()
{
"_id": ObjectId("575f1b138cc929dbcb20954e"),
"name": "babychen",
"registered": 1141570067,
"fullname": "Babychen Mathew",
"icon": "http://digg.com/users/babychen/l.png",
"profileviews": 24749
}

> db.stories.find({user: ObjectId("575f1b138cc929dbcb20954e")})
{
"_id": ObjectId("4ba267dc238d3ba3ca000001"),
"user": ObjectId("575f1b138cc929dbcb20954e"),
"href": "http://digg.com/people/Jedi_believer_who_refused_to_remove_hood_gets_an_apology",
"title": "'Jedi' believer who refused to remove hood gets an apology!",
...
```

Exercise: Get Stories Users

- Get all user names, story title and link that have topic **people**.
- Make sure you use only one request to the database to accomplish this task.

Note: A possible solution could be the following:

```
db.stories.aggregate([
    {$match: { "topic.name": "People" }},
    {$lookup: {from:"users", localField: "user", foreignField: "_id", as: "user"}},
    {$unwind: "$user"},
    {$project: {title:1, link:1, "username":"$user.name"} }])
```

- we need to `$match` the topic
- `$lookup` for the users name
- `$unwind` because the output of the `$lookup` is a array field
- `$project` only the link, title and username fields.

Exercise: Get Users Stories

- For every user, get all stories that have 100 comments or more.
- Again, perform this using only one request to the database.

Note: For this exercise a possible solution would be:

```
db.users.aggregate( [
  {$lookup: { from: "stories", foreignField: "user", localField: "_id", as: "stories"}},
  {$project: { stories: {$filter: {input: "$stories", as:"s", cond:{ $gte: ["$$s.comments", 100]}}}}}
]
```

- Make sure the students start aggregating from `users`
- They may ask whether starting with stories would have better performance.
  - Get them to think about indexes and filter operations.
- Ask the question:
  - Could we get the same info if we would start from stories ?
- Make sure you highlight the fact that we are using $filter[4]

Exercise: Sample Users

Get a random sample of five users, and their corresponding stories, where the user name starts with char `n`.

Note: The objective is to have the students look for the sample operator.

Students might come up with the following solution:

```
db.users.aggregate([ {$sample:{size:5}},{$match:{ name: /^n/  }}])
```

Note that this is incorrect. It does not select a sample of students whose username begins with 'n'. Rather it selects a sample of the entire collection and then filters out any students whose username does not begin with 'n'.

An accurate answer should be:

```
db.users.aggregate([ {$match:{ name: /^n/  }}, {$sample:{size:5}}])
```

We should also *$lookup* for the digg stories

```
db.users.aggregate([
  {$match:{ name: /^n/  }},
  {$sample:{size:5}},
  {$lookup: { from: "stories", foreignField: "user", localField: "_id", as: "stories"}},
])
```

---

[4] https://docs.mongodb.com/manual/reference/operator/aggregation/filter/

Exercise: Slice Users Stories

For each user that has four stories published, get the user's name and the last two stories!

Note: In this exercise we want students to explore the $slice[5] operator

```
db.users.aggregate([
  {$lookup: { from: "stories", foreignField: "user", localField: "_id", as: "stories"}},
  {$match: { stories: {$size: 4} }},
  {$project: { name:1, last_2_stories: {$slice: [ "$stories", -1, 2 ]}  }}
])
```

- $lookup for the left outer join
- $match will filter all users that have only 4 stories published
- $slice to project just the last 2 stories in the array

Exercise: Users Stories

From all users that have more than 100000 profile views, get their third story.

Note: In this exercise we want students to explore the $arrayElemAt[6] operator

```
db.users.aggregate([
  {$match: {profileviews: {$gt: 100000}}},
  {$lookup: { from: "stories", foreignField: "user", localField: "_id", as: "stories"}},
  {$project: { name: 1, third_story: { $arrayElemAt: ["$stories", 3]}  }}
])
```

---

[5] https://docs.mongodb.com/manual/reference/operator/aggregation/slice/
[6] https://docs.mongodb.com/manual/reference/operator/aggregation/arrayElemAt/

6 3.2 Cluster Operations

6.1 New Cluster Operations in MongoDB 3.2

Learning Objectives

Upon completing this module, students will be able to:

- Distinguish stale from dirty reads
- Use read concern in MongoDB 3.2
- Describe how read concern prevents dirty reads
- List the features of Replication Protocol 1
- List the benefits of using config servers as replica sets (CSRS)

Background: Stale Reads

- Reads that do not reflect the most recent writes are stale
- These can occur when reading from secondaries
- Systems with stale reads are "eventually consistent"
- Reading from the primary minimizes odds of stale reads
  - They can still occur in rare cases

Note:

- Stale reads see a view of the data that was in place at some point recently

---

Stale Reads on a Primary

- In unusual circumstances, two members may simultaneously believe that they are the primary
  - One can acknowledge `{ w : "majority" }` writes
    - This is the true primary
  - The other was a primary
    - But a new one has been elected
- In this state, the other primary will serve stale reads

Note:

- The scenario described here might happen if, for example, the other primary freezes for some time, then resumes operation
- This slide is for the benefit of engineers who are very knowledgeable about isolation, and who are concerned about isolation levels
  - Telling them that primaries prevent stale reads is not completely accurate

  - This is giving them a sense of why we don't simply say that.

Background: Dirty Reads

- Dirty reads are not stale reads
- Dirty reads occur when you see a view of the data
  - ... but that view *may* not persist
  - ... even in the history (i.e., oplog)
- Occur when data is read that has not been committed to a majority of the replica set
  - Because that data *could* get rolled back

Note:

- There is no way to know during a dirty read if its view of the data includes a write that will be rolled back
- Here is a good time to ask when writes can get rolled back
- Answers:
  - If a network partition isolates the primary, a new one will be elected
  - If the primary crashes, a new one will be elected and the old primary's writes will be rolled back

---

Dirty Reads and Write Concern

- Write concern alone can not prevent dirty reads
  - Data on the primary may be vulnerable to rollback
- Read concern was implemented to allow developers the option of preventing dirty reads

---

Note:

- Might be a good time to ask how many ways dirty reads can happen.
- Answers:
  - Primary gets a write, but crashes before the oplog sends data to the secondary
  - Primary and one secondary both get the write, but both crash before it gets to disk on either
  - Primary gets the write, but there is a network partition separating it from the secondaries; they elect a new primary
    - Write gets rolled back, so it's not in your data set unless manually added
- Don't let the students conflate read concern with read preference[7]

---

[7] https://docs.mongodb.com/manual/core/read-preference/

Introduction to Read Concern

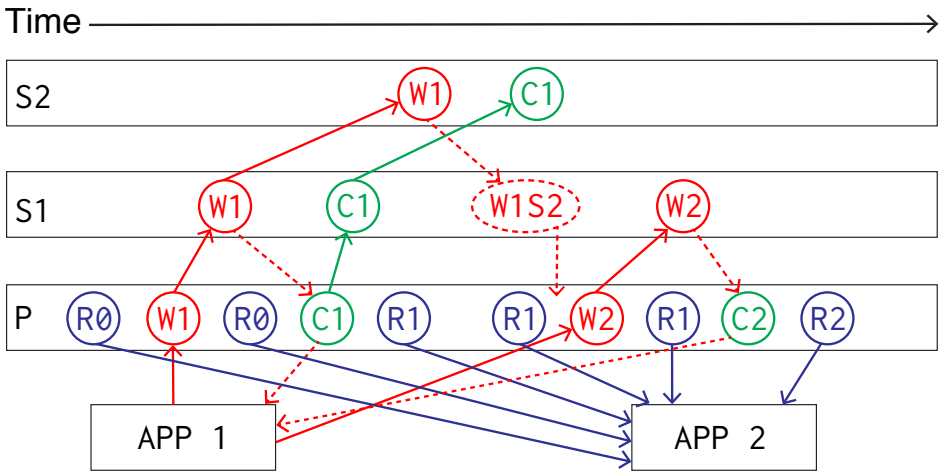
- Two settings
  - "local": read the most recent data on the server
    - This is the historical behavior.
    - Exposes the application to dirty reads
  - "majority": data updates only when majority acknowledged
    - A version of the data is retained pre-acknowledgment
    - Writes get committed after a majority has them
      - Committed first on the primary
      - When a majority acknowledges the write

Note: Questions to ask:

- Can I avoid dirty reads if I write a document with write concern "majority" and read preference: "primary"?
  - Answer: No. Without using read concern level : "majority", reads can be dirty
- What can happen if I use a write concern of `{ w: 1 }` and read concern level of "majority"?
  - Answer: You will not have dirty reads ... but you may be unable to read your own writes

---

Example: Read Concern Level Majority



Note:

- This looks quite complicated, but all it's really showing is:
  - Two writes, both from App 1, and the associated replication and responses (red and green)
  - Several reads at various times all from App 2 (blue)
- Note that the applications are using w : "majority" and read concern level: "majority"
- The application doesn't read a write until after the secondary has confirmed to the primary that it has received the write

---

- Key:
  - Red W's are the writes: W1 and W2, as they propagate through
    - Dashed red lines are acknowledgments of the writes
      - W1S2 is the acknowledgment of write 1 from the S2 server
  - Green C's are the read commits from read concern "majority".
    - C1 marks the moment where W1 has been committed
    - C2 marks the moment where W2 has been committed
    - The primary also gets a write acknowledgement when a commit occurs on the primary
    - Note that the commits go from primary to the secondaries, along with the oplog.
  - Blue R's are the reads from App 2 at various points in time
    - R0 is the initial state
    - R1 is the state after W1 has been committed
    - R2 is the state after W2 has been committed

Quiz

What is the difference between a dirty read and a stale read?

Note:

- Dirty read means you see a write that may not persist
- Stale read means you don't see a write that has occurred

Read Concern and Read Preference

- Read preference determines the server you read from
  - Primary, secondary, etc.
- Read concern determines the view of the data you see, and does not update its data the moment writes are received

Read Concern and Read Preference: Secondary

- The primary has the most current view of the data
  - Secondaries learn which writes are committed from the primary
- Data on secondaries might be behind the primary
  - But never ahead of the primary

Using Read Concern

- To use read concern, you must:
  - Use WiredTiger on all members
  - Launch all mongods in the set with
    * `--enableMajorityReadConcern`
  - Specify the read concern level to the driver
- You should:
  - Use write concern `{ w : "majority" }`
  - Otherwise, an application may not see its own writes

Note:

- If running with read concern level: "majority" but not write concern `{ w: "majority" }`, it would be possible to insert a document, get it acknowledged, and then try to read it back, but not see it.
- Obviously, users should not do this.

Example: Using Read Concern

- First, launch a replica set
  - Use `--enableMajorityReadConcern`
- A script is in the *shell_scripts* directory of the USB drive.

```
./launch_replset_for_majority_read_concern.sh
```

Note:

- This will allow them to launch a replica set that can use majority read concern.

#!/usr/bin/env bash

mkdir -p /data/replset/{1,2,3} wait mongod –replSet majrc –port 27017 –dbpath /data/replset/1 –logpath /data/replset/1/mongod.log –wiredTigerCacheSizeGB 1 –enableMajorityReadConcern –fork wait mongod –replSet majrc –port 27018 –dbpath /data/replset/2 –logpath /data/replset/2/mongod.log –wiredTigerCacheSizeGB 1 –enableMajorityReadConcern –fork wait mongod –replSet majrc –port 27019 –dbpath /data/replset/3 –logpath /data/replset/3/mongod.log –wiredTigerCacheSizeGB 1 –enableMajorityReadConcern –fork wait echo 'cfg = { "_id" : "majrc", "members" : [{ "_id" : 0, "host" : "localhost:27017", }] }; rs.initiate(cfg)' | mongo wait echo 'rs.add("localhost:27018")' | mongo wait echo 'rs.add("localhost:27019")' | mongo

---

Example: Using Read Concern (Continued)

```
#!/usr/bin/env bash
echo 'db.testCollection.drop();' | mongo --port 27017 readConcernTest; wait
echo 'db.testCollection.insertOne({message: "probably on a secondary." } );' |
     mongo --port 27017 readConcernTest; wait
echo 'db.fsyncLock()' | mongo --port 27018; wait
echo 'db.fsyncLock()' | mongo --port 27019; wait
echo 'db.testCollection.insertOne( { message : "Only on primary." } );' |
     mongo --port 27017 readConcernTest; wait
echo 'db.testCollection.find().readConcern("majority");' |
     mongo --port 27017 readConcernTest; wait
echo 'db.testCollection.find(); // read concern "local"' |
```

Note:

- In this example, students can see that one document will propagate to the secondaries.
- But the second document, while present on the primary, will not replicate.
- Encourage them to use their own example (with `db.fsyncLock` on secondaries).
  - They can use a driver, if they wish.

Quiz

What must you do in order to make the database return documents that have been replicated to a majority of the replica set members?

Note: Answer:

- Invoke the mongod with `--enableMajorityReadConcern`
- Use `cursor.readConcern("majority")` on a read
  - Alternatively, use read concern level “majority” with a driver’s connection pool

---

Replication Protocol Version 1

- MongoDB 3.2 introduced a new replication protocol.
  - Replication protocol version 1 is the new protocol.
  - Replication protocol version 0 was used in earlier versions of MongoDB.
- With version 1, secondaries now write to disk before acknowledging writes.
- `{ w : "majority" }` now implies `{ j : true }`
- Set the replication protocol version using the `protocolVersion` parameter in your replica set configuration.
- Version 1 is the default in MongoDB >=3.2.

Replication Protocol Version 1 (continued)

- Also adds `electionTimeoutMillis` as an option
  - For secondaries: How long to wait before calling for an election
  - For primaries: How long to wait before stepping down
    - After losing contact with the majority
    - This applies to the primary only
- Required for read concern level "majority"

Note:

- The old replication protocol is now known as replication protocol 0
- Previously, secondaries would acknowledge writes before those writes were journaled
- A short `electionTimeoutMillis` can result in lots of elections, especially with a flaky network
- A long `electionTimeoutMillis` can result in lower availability due to longer failover time

---

CSRS: Config Servers as Replica Sets

- With MongoDB 3.2, config servers can be replica sets
  - Subject to all standard rules of a replica set
  - Using read concern level "majority"
- Your config server replica set needs a primary
  - Without a primary, the config metadata can't change
    - No chunk splits, no chunk migrations
    - This will last until a new primary is elected

Note:

- There are some constraints to a replica set:
  - No arbiters
  - No delayed members
  - Requires replication protocol version 1

CSRS: Advantages

- Provides the same availability guarantees as your data
- Provides the same durability guarantees as your data
- You can tune the size of the replica set
  - Not restricted to 3 servers
  - Suitable for large deployments across data centers

Quiz

What are the advantages of replication protocol 1?

Note:

- `electionTimeoutMillis` now tunable
- Secondaries write to the journal before acknowledging
- Enables read concern "majority"
  - This enables config servers as replica sets

Quiz

What are the advantages of config servers as replica sets (CSRS)?

Note:

- You can get the same availability and durability guarantees as you have for your data
- You can tune the size of the config server set

---

7 Security

7.1 Authorization

Learning Objectives

Upon completing this module, students should be able to:

- Outline MongoDB's authorization model
- List authorization resources
- Describe actions users can take in relation to resources
- Create roles
- Create privileges
- Outline MongoDB built-in roles
- Grant roles to users

Authorization vs Authentication

Authorization and Authentication are generally confused and misinterpreted concepts:

- Authorization defines the rules by which users can interact with a given system:
  - Which operations can they perform
  - Over which resources
- Authentication is the mechanism by which users identify and are granted access to a system:
  - Validation of credentials and identities
  - Controls access to the system and operational interfaces

Authorization Basics

- MongoDB enforces a role-based authorization model.
- A user is granted roles that determine the user's access to database resources and operations.

The model determines:

- Which roles are granted to users
- Which privileges are associated with roles
- Which actions can be performed over different resources

Note:

- You can bring up the following questions:
  - What are privileges?
  - What kind of resources can be found on a typical database?
- Have some open discussion about what defines an action.
- Also you can take the opportunity to give examples of different roles in a company and how they are organized in terms of procedures and resources.

What is a resource?

- Databases?
- Collections?
- Documents?
- Users?
- Nodes?
- Shard?
- Replica Set?

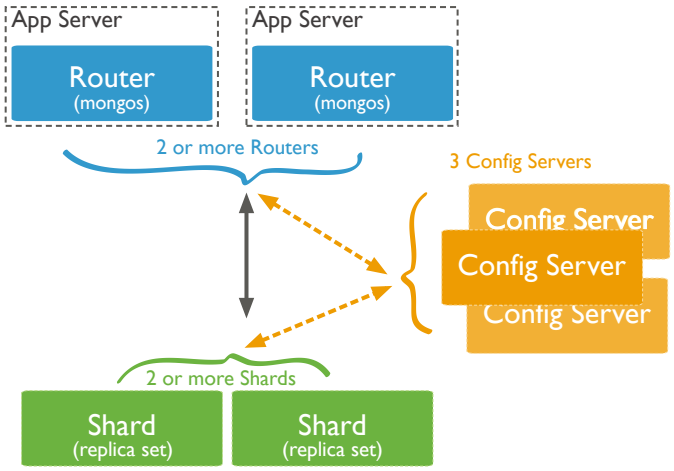
Note:

- A resource is a database, collection, set of collections, or the cluster.
- If the resource is the cluster, the affiliated actions affect the state of the system rather than a specific database or collection.

Authorization Resources

- Databases
- Collections
- But that is not all. See next several slides.

Cluster Resources



Note:

- Given the distributed nature of our database, MongoDB includes the cluster resource in the authorization module.
- Replica sets and shards comprise the cluster domain.

Types of Actions

Given a resource, we can consider the available actions:

- Query and write actions
- Database management actions
- Deployment management actions
- Replication actions
- Sharding actions
- Server administration actions
- Diagnostic actions
- Internal actions

Note:

- Actions are the operations that one can perform on database resources.
- The actions above are grouped by purpose.

- This organization is logical, not operational.
- Here we can ask the students which common operations they are familiar with while operating with a database and how those translate to MongoDB operations.

Specific Actions of Each Type

Query / Write	Database Mgmt	Deployment Mgmt
find	enableProfiler	planCacheRead
insert	createIndex	storageDetails
remove	createCollection	authSchemaUpgrade
update	changeOwnPassword	killop
	...	...

See the complete list of actions[8] in the MongoDB documentation.

Note: These are just a few examples of the list of actions available. The full list is available in MongoDB docs: https://docs.mongodb.org/v3.0/reference/privilege-actions/#privilege-actions

---

Authorization Privileges

A privilege defines a pairing between a resource as a set of permitted actions.

Resource:

```
{"db": "yourdb", "collection": "mycollection"}
```

Action: `find`

Privilege:

```
{
  resource: {"db": "yourdb", "collection": "mycollection"},
  actions: ["find"]
}
```

Note:

- We want to explain that we can set a privilege that enables multiple actions on a given resource.
- Also important to highlight that we can set *loose* resources like `all databases` or `all collections`

```
{
  resource: {"db": "", "collection": ""},
  actions: ["find", "insert"]
}
```

---

[8] https://docs.mongodb.com/manual/reference/privilege-actions/

Authorization Roles

MongoDB grants access to data through a role-based authorization system:

- Built-in roles: pre-canned roles that cover the most common sets of privileges users may require
- User-defined roles: if there is a specific set of privileges not covered by the existing built-in roles you are able to create your own roles

Built-in Roles

Database Admin	Cluster Admin	All Databases
dbAdmin	clusterAdmin	readAnyDatabase
dbOwner	clusterManager	readWriteAnyDatabase
userAdmin	clusterMonitor	userAdminAnyDatabase
	hostManager	dbAdminAnyDatabase

Database User	Backup & Restore
read	backup
readWrite	restore

Superuser	Internal
root	__system

Note: Built-in roles have been created given the generic users that interact with a database and their respective tasks.

- Database user roles: should be granted to application-side users;
- Database administrators: roles conceived for system administrator, DBAs and security officers
- Cluster Administrator roles: mostly for system administrators and DBAs; individuals that will deal with the overall administration of deployments
- Backup and Restore: for applications that perform only backup and restore operations – Cloud and Ops manager, for example
- All Database Roles: for global administrators of a deployment. If you want to avoid granting the same role for every single database
- Superuser: root level operations. Generally the first user that you create on any give system should probably have a root role and then add other specific users.
- Internal: it's documented, it's public but don't mention it too much. This a backdoor that only the cluster members (other replica set members, or a mongos) should have access to. Do not assign this role to user objects representing applications or human administrators.

Built-in Roles

To grant roles while creating an user:

```
use admin
db.createUser(
  {
    user: "myUser",
    pwd: "$up3r$3cr7"
    roles: [
      {role: "readAnyDatabase", db: ""},
      {role: "dbOwner", db: "superdb"},
      {role: "readWrite", db: "yourdb"}
    ]
  }
)
```

Built-in Roles

To grant roles to existing user:

```
use admin
db.grantRolesToUser( {
  "reportsUser",
  [
    { role: "read", db: "accounts" }
  ]
} )
```

User-defined Roles

- If no suitable built-in role exists, we can can create a role.
- Define:
  - Role name
  - Set of privileges
  - List of inherit roles (optional)

```
use admin
db.createRole({
  role: "insertAndFindOnlyMyDB",
  privileges: [
    {resource: { db: "myDB", collection: "" }, actions: ["insert", "find"]}
  ],
  roles: []})
```

Role Privileges

To check the privileges of any particular role we can get that information using the `getRole` method:

```
db.getRole("insertAndFindOnlyMyDB", {showPrivileges: true})
```

Note: There are many other authorization and user management commands and options that you should get your students acquainted with. All of those can be found in the security reference[9]

The output of this slide command is should be similar to the following:

```
{
"role": "insertAndFindOnlyMyDB",
"db": "admin",
"isBuiltin": false,
"roles": [ ],
"inheritedRoles": [ ],
"privileges": [
  {
    "resource": {
      "db": "myDB",
      "collection": ""
    },
    "actions": [
      "find",
      "insert"
    ]
  }
],
"inheritedPrivileges": [
  {
    "resource": {
      "db": "myDB",
      "collection": ""
    },
    "actions": [
      "find",
      "insert"
    ]
  }
 ]
}
```

---

[9] https://docs.mongodb.org/manual/reference/security/

7.2 Authentication

Learning Objectives

Upon completing this module, you should understand:

- Authentication mechanisms
- External authentication
- Native authentication
- Internal node authentication
- Configuration of authentication mechanisms

Authentication

- Authentication is concerned with:
  - Validating identities
  - Managing certificates / credentials
  - Allowing accounts to connect and perform authorized operations
- MongoDB provides native authentication and supports X509 certificates, LDAP, and Kerberos as well.

Authentication Mechanisms

MongoDB supports a number of authentication mechanisms:

- SCRAM-SHA-1 (default >= 3.0)
- MONGODB-CR (legacy)
- X509 Certificates
- LDAP (MongoDB Enterprise)
- Kerberos (MongoDB Enterprise)

Note:

- Native: SCRAM-SHA-1 and MongoDB-CR are native mechanisms in the sense that they are fully managed by MongoDB instances.
- External: LDAP and Kerberos are external authentication mechanisms and are only available with MongoDB Enterprise.
- X509 can also be considered native in terms of management but they rely on certificates generated by 3rd parties and only enforced by MongoDB.

Internal Authentication

For internal authentication purposes (mechanism used by replica sets and sharded clusters) MongoDB relies on:

- Keyfiles
  - Shared password file used by replica set members
  - Hexadecimal value of 6 to 1024 chars length
- X509 Certificates

Simple Authentication Configuration

To get started we just need to make sure we are launching our mongod instances with the `--auth` parameter.

```
mongod --dbpath /data/db --auth
```

For any connections to be established to this mongod instance, the system will require a username and password.

```
mongo -u user -p
Enter password:
```

Note:

- Using the `--auth` parameter will only cause mongod to enable authentication.
- You need to create users separately.
- You can take the opportunity to ask:
  - Q: What happens if we just launch a mongod without having any users created?
  - A: Nothing happens, we just can't access the instance.

7.3 Lab: Secure mongod

Premise

It is time for us to get started setting up our first MongoDB instance with authentication enabled!

Note:

- Expected time: 5 minutes
- Prerequisites:
  - Students should have installed MongoDB Enterprise or compiled MongoDB community with –ssl flags.

Launch `mongod`

Let's start by launching a `mongod` instance:

```
mkdir /data/secure_instance_dbpath
mongod --dbpath /data/secure_instance_dbpath --port 28000
```

At this point there is nothing special about this setup. It is just an ordinary `mongod` instance ready to receive connections.

Root level user

Create a `root` level user:

```
mongo --port 28000 admin  // Puts you in the _admin_ database

use admin
db.createUser( {
  user: "maestro",
  pwd: "maestro+rules",
  customData: { information_field: "information value" },
  roles: [ {role: "root", db: "admin" } ]
} )
```

Note: *root* is a superuser role so make sure you mention the privileges.

https://docs.mongodb.org/manual/reference/built-in-roles/#superuser-roles

---

Enable Authentication

Launch `mongod` with `auth` enabled

```
mongo admin --port 28000 --eval 'db.shutdownServer()'
mongod --dbpath /data/secure_instance_dbpath --auth
```

Note: With these commands, you can mention that:

- *mongo admin –eval 'db.shutdownServer()'* is a clean shutdown of the server
- `timeoutSecs` is parameter that can be used to control the shutdown operation
- Especially w/ Replica Sets, which they'll be using, soon.

Connect using the recently created `maestro` user.

```
mongo --port 28000 admin -u maestro -p
```

7.4 Encryption

Learning Objectives

Upon completing this module, students should understand:

- The encryption capabilities of MongoDB
- Network encryption
- Native encryption
- Third party integrations

Encryption

MongoDB offers two levels of encryption

- Transport layer
- Encryption at rest (MongoDB Enterprise >=3.2)

Note:

- important to note to students that encryption at rest is an enterprise version feature

---

Network Encryption

- MongoDB enables TLS/SSL for transport layer encryption of traffic between nodes in a cluster.
- Three different network architecture options are available:
  - Encryption of application traffic connections
  - Full encryption of all connections
  - Mixed encryption between nodes

Note:

- mixed encryption means that we can have nodes in a replica set that communicate with some nodes not encrypted and others encrypted

---

Native Encryption

MongoDB Enterprise comes with a encrypted storage engine.

- Native encryption supported by WiredTiger
- Encrypts data at rest
  - AES256-CBC: 256-bit Advanced Encryption Standard in Cipher Block Chaining mode (default)
    - symmetric key (same key to encrypt and decrypt)
  - AES256-GCM: 256-bit Advanced Encryption Standard in Galois/Counter Mode
  - FIPS is also available
- Enables integration with key management tools

Encryption and Replication

- Encryption is not part of replication:
  - Data is not natively encrypted on the wire
    - Requires transport encryption to ensure secured transmission
  - Encryption keys are not replicated
    - Each node should have their own individual keys

Note:

- Important to raise awareness to this point
- Many students might get the impression that configuring encryption in one of the nodes would be enough when that's not the case
- Wire data needs to encrypted through TLS/SSL configuration
- Encrypted Storage Engine only provides encryption on data at rest
- We should use different encryption keys for different nodes.

Third Party Integration

- Key Management Interoperability Protocol (KMIP)
  - Integrates with Vormetric Data Security Manager (DSM) and SafeNet KeySecure
- Storage Encryption
  - Linux Unified Key Setup (LUKS)
  - IBM Guardium Data Encryption
  - Vormetric Data Security Platform
    - Also enables Application Level Encryption on per-field or per-document
  - Bitlocker Drive Encryption

Note:

- MongoDB offers some integration options for Key Management and Storage Encryption

---

- Key managers are recommended for good security practices like key expiration and rotation
- Key managers are important if we want to be complaint with HIPAA, PCI-DSS, and FERPA certifications

---

7.5 Lab: Secured Replica Set - KeyFile (Optional)

Premise

Security and Replication are two aspects that are often neglected during the Development phase to favor usability and faster development.

These are also important aspects to take in consideration for your Production environments, since you probably don't want to have your production environment **Unsecured** and without **High Availability**!

This lab is to get fully acquainted with all necessary steps to create a secured replica set using the `keyfile` for cluster authentication mode

Setup Secured Replica Set

A few steps are required to fully setup a secured Replica Set:

1. Instantiate one `mongod` node with no `auth` enabled
2. Create a `root` level user
3. Create a `clusterAdmin` user
4. Generate a keyfile for internal node authentication
5. Re-instantiate a `mongod` with `auth` enabled, `keyfile` defined and `replSet` name
6. Add Replica Set nodes

We will also be basing our setup using MongoDB configuration files[10]

Note:

- This might be a good opportunity to have students work in groups.
- If we can guarantee:
  - connectivity between all students workstations
  - administration rights over the workstations
- Then we can go ahead and group students together to accomplish these tasks.

---

[10] https://docs.mongodb.org/manual/reference/configuration-options/

Instantiate `mongod`

This is a rather simple operation that requires just a simple instruction:

```
$ pwd
/data
$ mkdir -p /data/secure_replset/{1,2,3}; cd secure_replset/1
```

Then go to this yaml file[11] and copy it into your clipboard

```
$ pbpaste > mongod.conf; cat mongod.conf
```

Instantiate `mongod` (cont'd)

```
systemLog:
  destination: file
  path: "/data/secure_replset/1/mongod.log"
  logAppend: true
storage:
  dbPath: "/data/secure_replset/1"
  wiredTiger:
    engineConfig:
      cacheSizeGB: 1
net:
  port: 28001
processManagement:
  fork: true
# setParameter:
#   enableLocalhostAuthBypass: false
# security:
#   keyFile: /data/secure_replset/1/mongodb-keyfile
```

Instantiate `mongod` (cont'd)

After defining the basic configuration we just need to call `mongod` passing the configuration file.

```
mongod -f mongod.conf
```

Note: If not mentioned before this is a good opportunity to have the students review the configuration options that MongoDB configuration files have.

Make sure you emphasize the security options:

https://docs.mongodb.org/manual/reference/configuration-options/#security-options

---

[11] https://github.com/thatnerd/work-public/blob/master/mongodb_trainings/secure_replset_config.yaml

Create root user

We start by creating our typical `root` user:

```
$ mongo admin --port 28001

> use admin
> db.createUser(
{
  user: "maestro",
  pwd: "maestro+rules",
  roles: [
    { role: "root", db: "admin" }
    ]
})
```

Create clusterAdmin user

We then need to create a clusterAdmin user to enable management of our replica set.

```
$ mongo admin --port 28001

> db.createUser(
{
  user: "pivot",
  pwd: "i+like+nodes",
  roles: [
    { role: "clusterAdmin", db: "admin" }
    ]
})
```

Generate a keyfile

For internal Replica Set authentication we need to use a keyfile.

```
openssl rand -base64 741 > /data/secure_replset/1/mongodb-keyfile
chmod 600 /data/secure_replset/1/mongodb-keyfile
```

Add keyfile to the configuration file

Now that we have the *keyfile* generated it's time to add that information to our configuration file. Just un-comment the last few lines.

```
systemLog:
  destination: file
  path: "/data/secure_replset/1/mongod.log"
  logAppend: true
storage:
  dbPath: "/data/secure_replset/1"
net:
  port: 28001
processManagement:
  fork: true
setParameter:
  enableLocalhostAuthBypass: false
```

```
security:
  keyFile: /data/secure_replset/1/mongodb-keyfile
```

Note:

- On this configuration we are focusing on getting the internal authentication to work with a keyfile.
- There are other options that you may want to bring up with the students.
- It's probably a good time to ask?
  - If I want to use x509 certificates what other settings would I need to be adding?
  - Once I configured the system to use keyfile is that immutable?

Configuring Replica Set

- Now it's time to configure our Replica Set
- The desired setup for this Replica Set should be named "VAULT"
- It should consist of 3 data bearing nodes

Note:

We expect the students to first draft a set of instructions that they need to complete:

- Add the replication configuration to the config file
- Connect with *pivot* user to initiate the replica set
- Instantiate the remaining nodes
- Add those nodes to the replica set

The end result should be something similar to the following:

```
> rs.isMaster()
{
"setName" : "VAULT",
"setVersion" : 3,
"ismaster" : true,
"secondary" : false,
"hosts" : [
  "node0:50000",
  "node1:50000",
  "node2:50000"
],
...
}
```

They will probably have something to add to their config files.

Here's the link[12]

and it looks like this:

```
replication:
  oplogSizeMB: 100
```

[12] https://github.com/thatnerd/work-public/blob/master/mongodb_trainings/secure_replset_config_including_replset_options.yaml

```
  replSetName: "VAULT"
  enableMajorityReadConcern: true
```