Document Stores – Hands On

23D020: Big Data Management for Data Science

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Session goals

- Get familiar with MongoDB
  - Set up a MongoDB server
  - MongDB Shell
  - MongoDB Python API
  - Aggregation Framework
  - Geospatial queries
- Understand the implication of different models
  - Normalization vs denormalization

MongoDB Tools

MongoDB tools

- **MongoDB Community Server**
  - The Community Edition of the MongoDB distributed document database
- **MongoDB Shell**
  - A command line interface that allows to work (i.e., query and update) with your database
- **MongoDB Compass**
  - A graphical user interface for MongoDB
- **MongoDB Tools**
  - Command line utilities for working with MongoDB

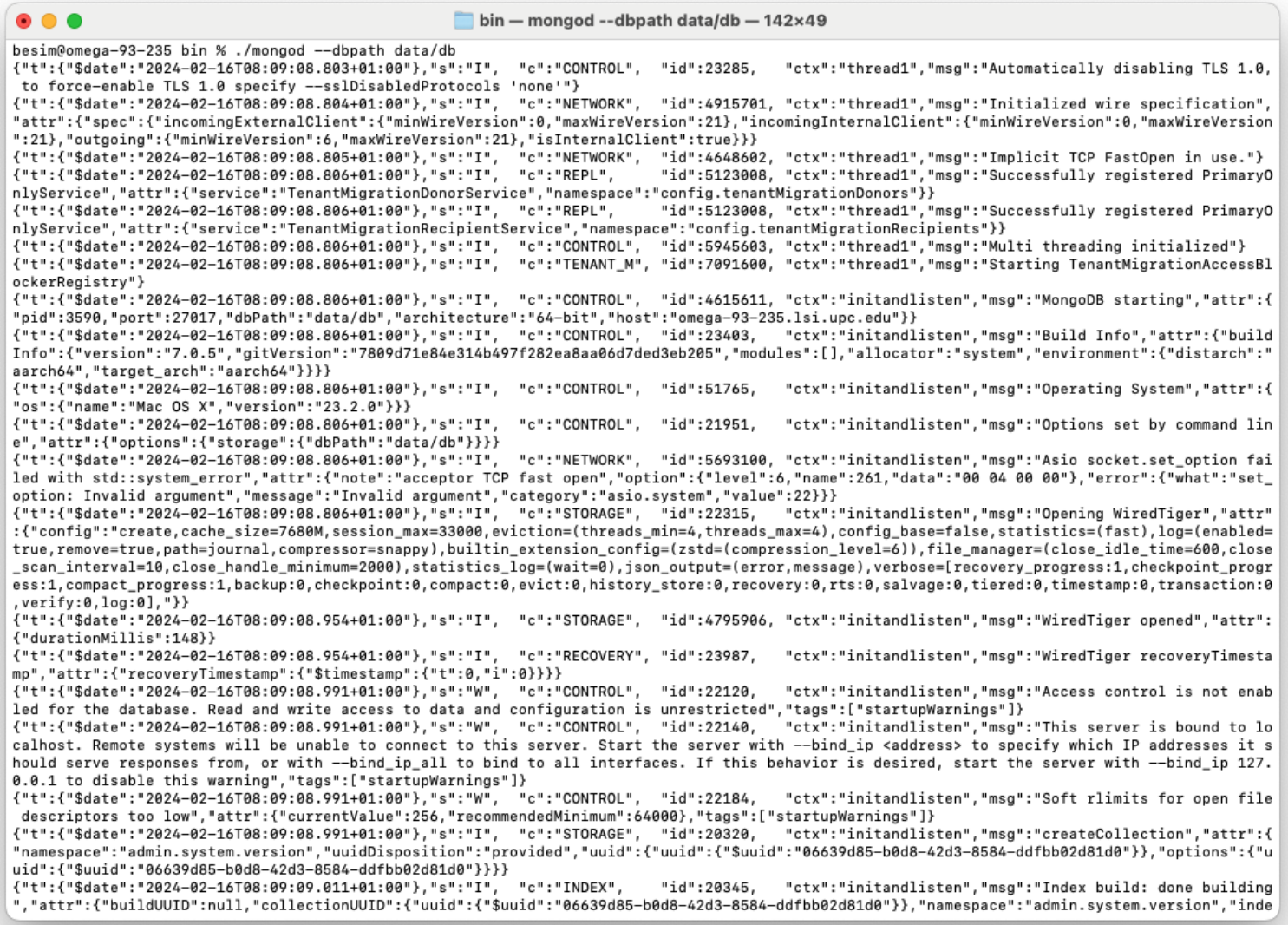
Setting up MongoDB (1/3)

MongoDB Community Server

- https://www.mongodb.com/try/download/community
- Run the server
  - `./mongod –dbpath folder`
  - `folder`: to store the data, you can create your own folder and relate to it, or use the default one `/data/db` , but you need to make sure the latter exists with the right read/write permissions.

Setting up MongoDB (1/4)

MongoDB Community Server



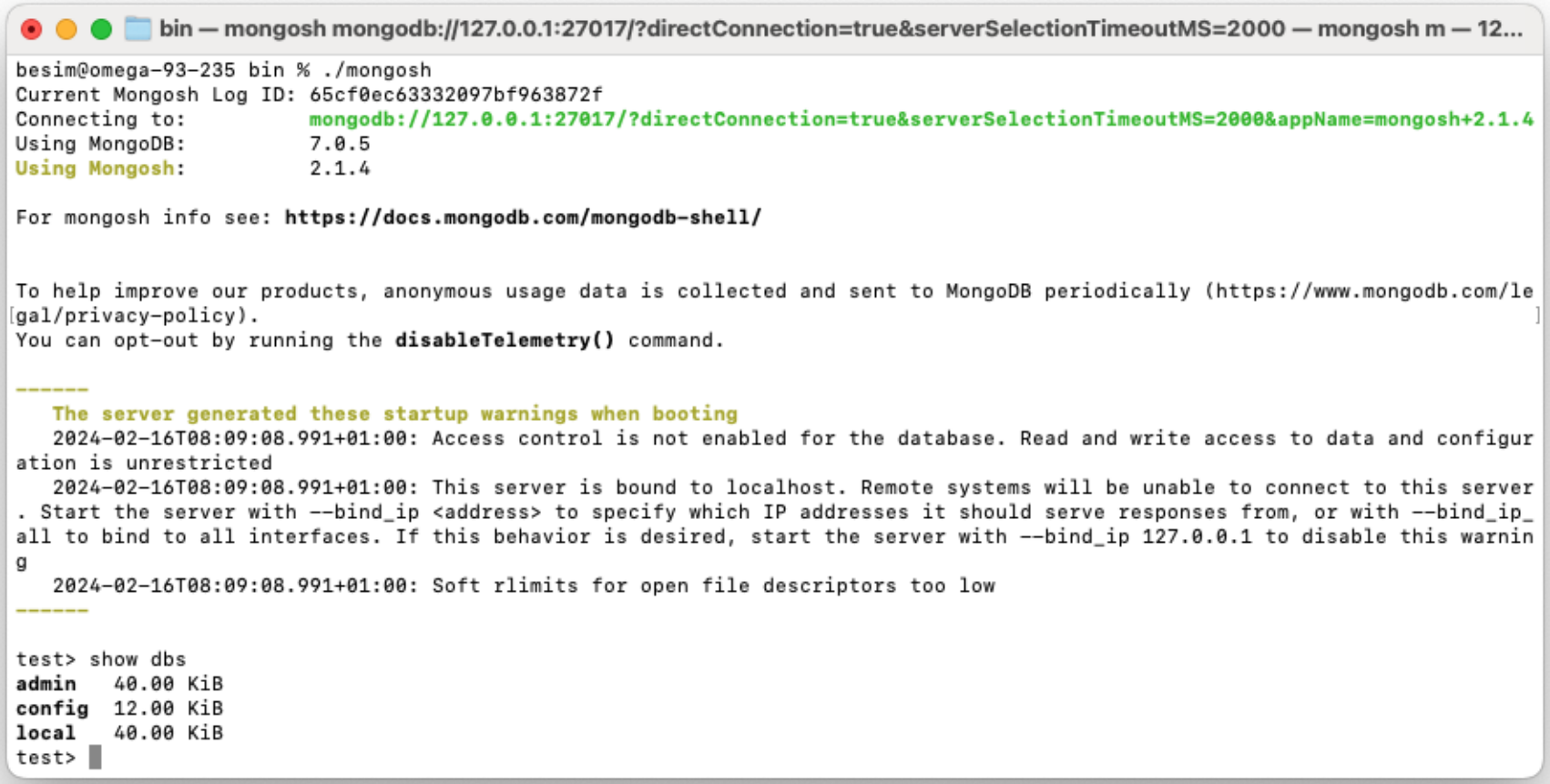
Setting up MongoDB (2/4)

MongoDB Shell

- The database shell (interaction with the server)
- If not installed, download it from here
  - https://www.mongodb.com/try/download/shell
- With the server running, run the shell on a separate terminal
  - `./mongosh –-host --port`
  - `--host:` defaults to `127.0.0.1`
  - `--port:` defaults to `27017`

Setting up MongoDB (2/4)

MongoDB Shell



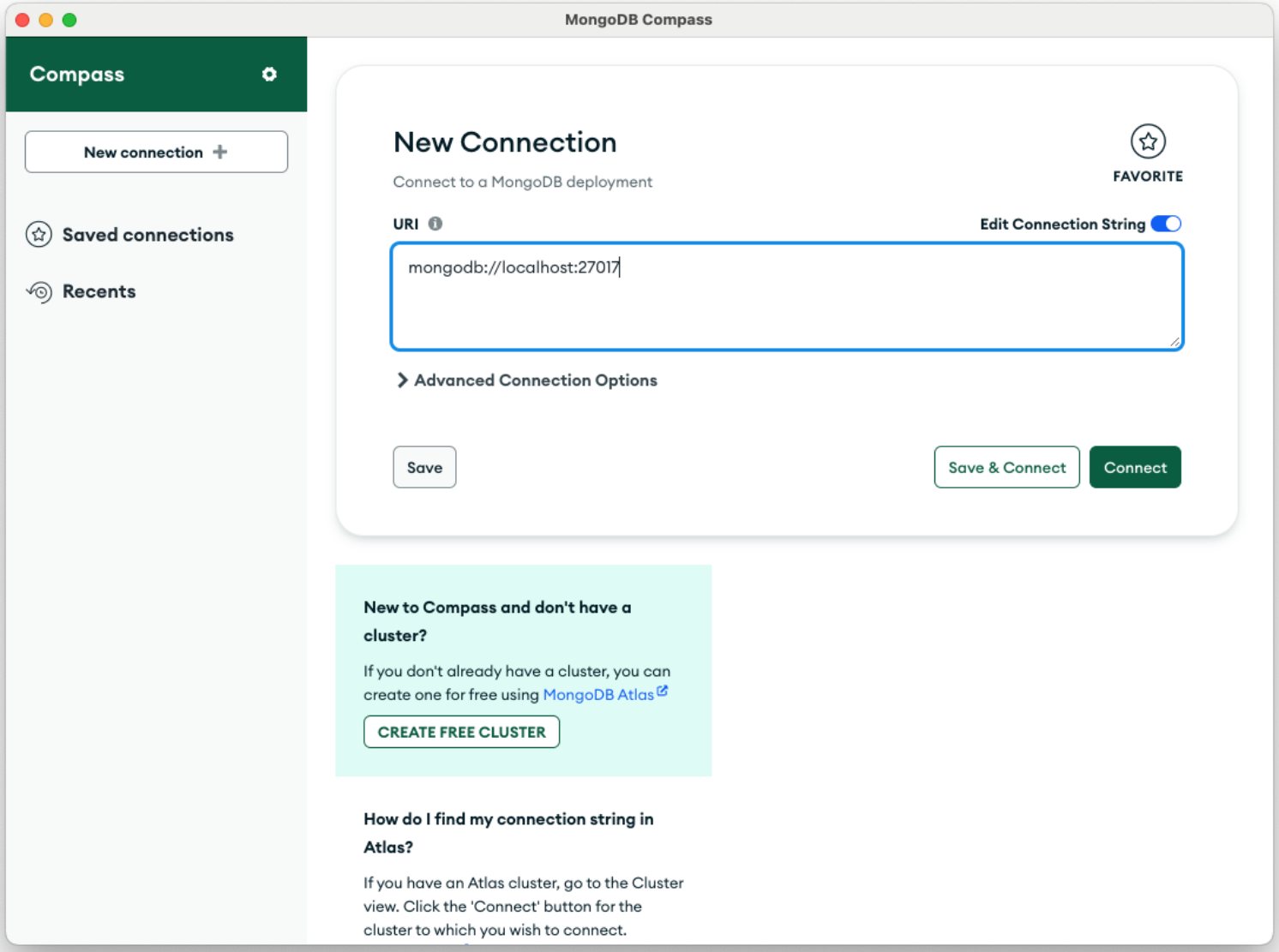
Setting up MongoDB (3/4)

MongoDB Compass

- Interactive tool for querying, optimizing, and analyzing MongoDB data
- Link to download
  - https://www.mongodb.com/try/download/compass
- Execute it as a usual application in the system

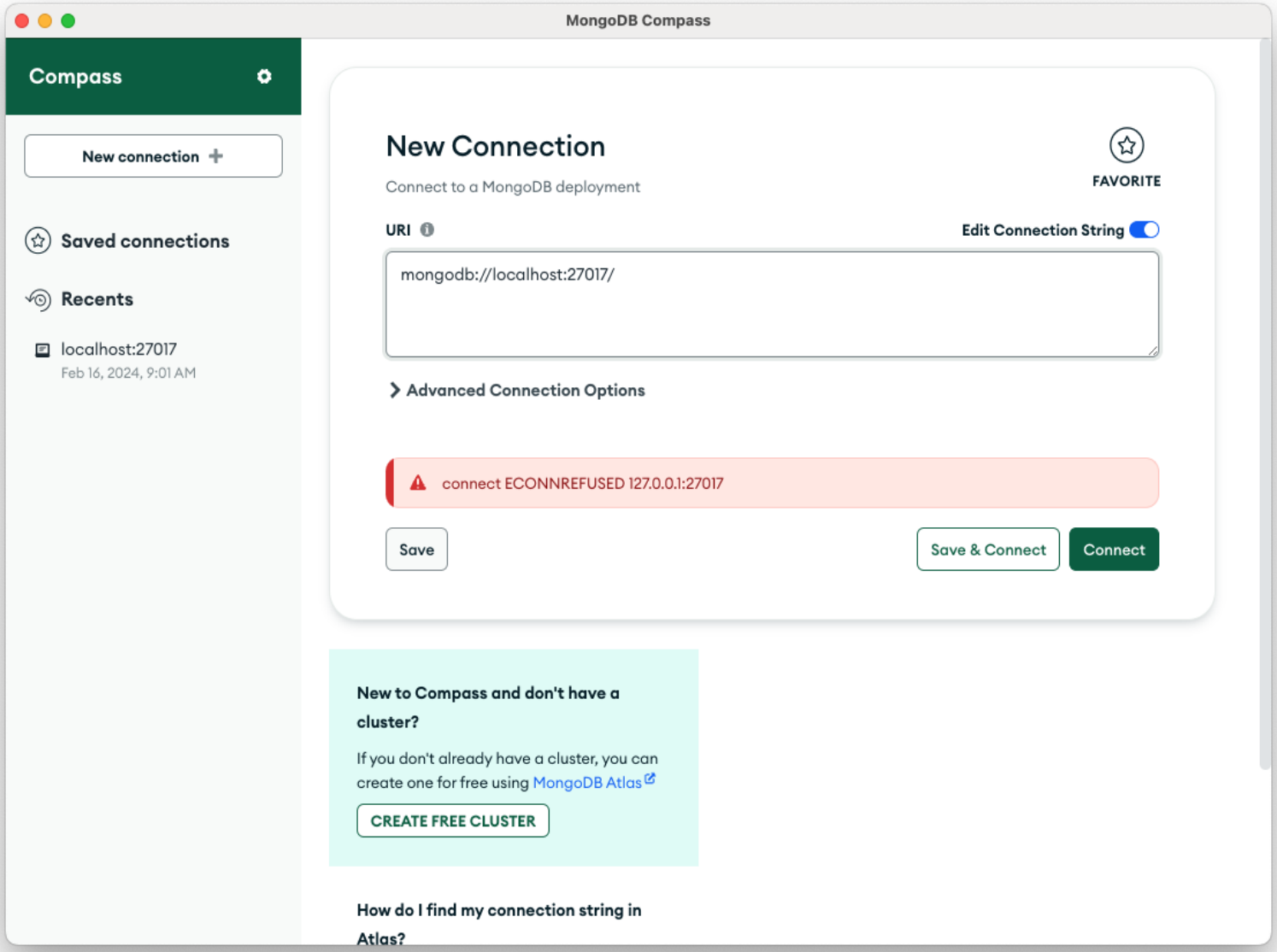
Setting up MongoDB (3/4)

MongoDB Compass



Setting up MongoDB (3/4)

MongoDB Compass



Setting up MongoDB (4/4)

MongoDB Database Tools

- Collection of command-line utilities for working with a MongoDB deployment
- Download link
  - https://www.mongodb.com/try/download/database-tools
- Tools provided
  - `./mongoimport`
  - `./mongoexport`
  - `./mongodump`
  - `./mongostat`
  - …

Querying in MongoDB

Documents and collections

- Documents are ordered set of keys with associated values
  - Most languages have a data structure that is a natural fit:
    - Map, Hash, Dictionary, Object –> JSON (BSON)

      {“greeting” : “Hello, world!”, “foo” : 3}
- Keys in a document must be Strings
  - No duplicate keys
- Documents (rows) are grouped into Collections (tables)
  - Collections are Schemaless

Documents and collections

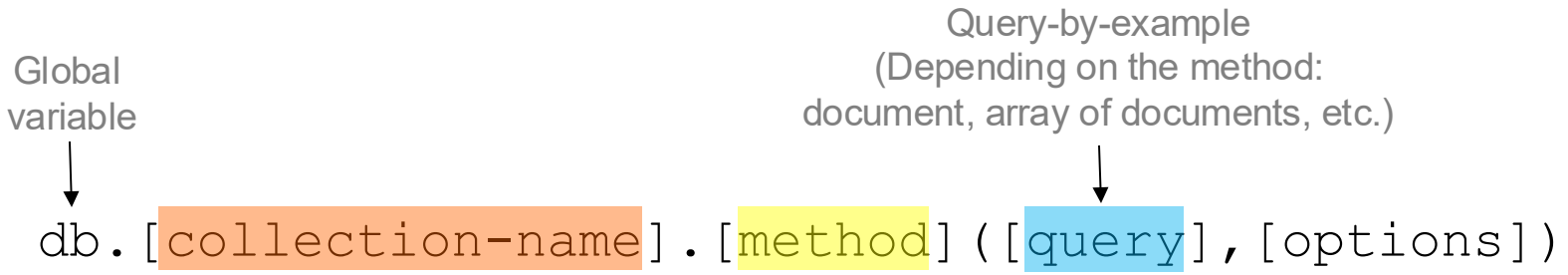
- Basic Data Types
  - null, Boolean, Integer, String, Binary, …
- Complex Data Types
  - Array, Embedded Documents, Date, …
- Special Data Types

  ObjectIds : "_id"
  - Unique value representing the document key
  - 12 bytes

Example: Student document

```
{
 "_id": ObjectId
       ("507f1f77bcf86cd799439011")
 "name": "Marc"
 "courses": [
        "DB", "BDM", "DEBD"
 ]
 "address": {
        "street": "Carrer de Sants"
        "number": 19
        "city": "Barcelona"
 }
}
```

MongoDB syntax



- Collection methods: insert, update, remove, find, …

```
db.restaurants.find({"name": "x"})
```

- Cursor methods: forEach, hasNext, count, sort, skip, size, ...

```
db.restaurants.find({"name": "x"}).count()
```

- Database methods: createCollection, copyDatabase, ...

```
db.createCollection("collection-name")
```

- …

Syntax - operators

- Query and Projection operators
  - Comparison ops: `$eq, $gt, $gte, $in, $nin, $lt, $lte`

    `{field: {$eq: <value>}}`
  - Logical ops: `$and, $not, $nor, $or`

    `{$and: [{<expression1>},…,{<expressionN>}]}`
  - Array ops: `$push, $pull, $addToSet, $all, $elemMatch`

    `{<field>:{$elemMatch:{<query1>,<query2>,…}}}`
- Update operators: `$set, $inc, $min, $max, …`
- …

Insert Documents

- Insert one or more documents to the people collection

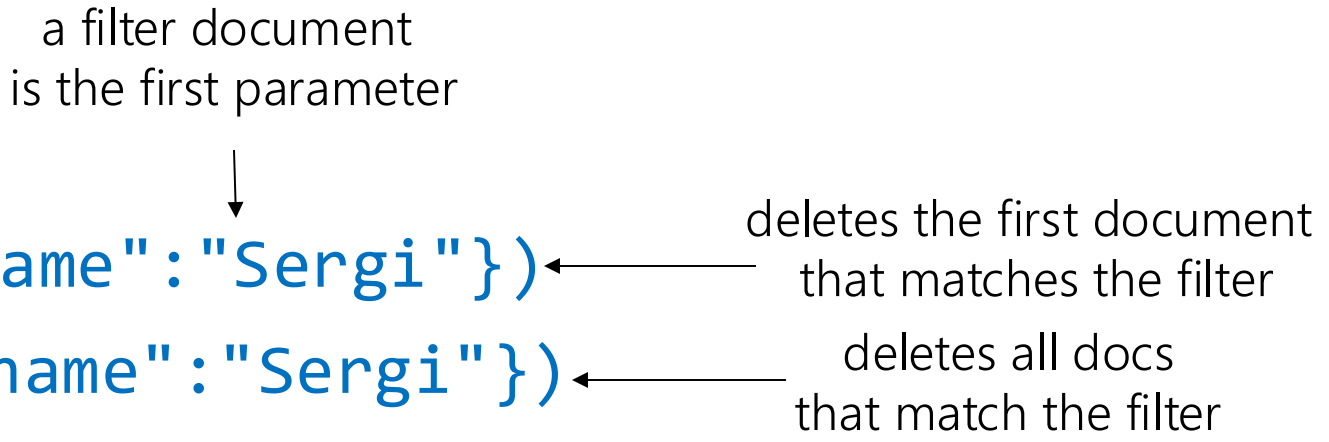
```
db.users.insertOne({“name”:”Sergi”})
```
document

```
db.users.insertMany([{“name”:”Sergi”},{“name”:..}])
```
array

- Insert will add an "_id" key to the document (if you do not provide one)
  - You can use a custom id, by adding a field “_id” to inserted documents
- MongoDB checks that the document does not exceed 16MB

Documentation: https://docs.mongodb.org/manual/tutorial/insert-documents/

Delete Documents



- Removing by example
- Remove all documents. Collection and indexes remain intact!

```
db.users.deleteMany({})
```

- Drop a collection; it is faster. You need to recreate indexes!

```
db.users.drop()
```


Documentation: https://docs.mongodb.org/manual/tutorial/remove-documents/

Modify/Update Document Schema

mongo shell

Get document to update

```
> var joe = db.users.findOne({"name":"joe"});
```

Create "username" / Delete "name"

```
> joe.username = joe.name;
> delete joe.name;
```

Create relationships / Delete "friends" and "enemies"

```
> joe.relationships={"friends":joe.friends,"enemies":joe.enemies};
> delete joe.friends;
> delete joe.enemies;
```

Store updated document

```
> db.users.replaceOne({"name":"joe"},joe)
```

make sure that your update always specifies a unique document, e.g., use _id

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Documentation: https://docs.mongodb.org/manual/tutorial/modify-documents/

Update Document Values

- Looks for docs that match the query and updates spec. fields

```
db.users.updateMany({"name":"Sergi"}),
{$set:{“address":“..."}})
```

Update operator → `$set` ← Update the field or create it

- Update only the first doc that matches the query

```
db.collection.updateOne({filterDoc},{updateDoc})
```

- “Upsert option” `updateOne({…},{…},{"upsert" : true})`
  - If no document matches the query, it creates a new document
  - Should be used with caution

Documentation: https://docs.mongodb.org/manual/tutorial/modify-documents/

Update Arrays

- **“$push”** operator adds elements to the end of an array if the array exists and creates a new array if it does not

```
db.users.updateOne({"name":"Sergi"},
                   {"$push":{"emails":{"email":"sn@php.net"}}})
...{"$push" : {"emails" : {"$each" : ["a","b","c"]}}})
```

“modifier”, push multiple elements in one operation

- **“addToSet”** operator in combination with the “$each” modifier adds multiple unique values

```
db.users.updateOne({"name":"Sergi"},
  {"$addToSet" : {"emails" : {"$each" :[“sn@php.net", “sn@example.com",
“sne@python.org"]
```

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Documentation: https://docs.mongodb.org/manual/reference/operator/update-array

Query Documents

- Find all documents in a collection

```
db.users.find()
```

- Query by example (build a document that looks similar to the one you want)

```
db.users.find({“username”:“oscar”})
```

- Attribute projection, specify which keys to return

```
> db.users.find({}, {"username" : 1, "email" : 1})
{
    "_id" : ObjectId("4ba0f0dfd22aa494fd523620"),
    "username" : "joe",
    "email" : "joe@example.com"
}
```

To prevent "_id" from being returned: …{…,“_id”:0}

Query Documents (II)

Operators: comparison, logical, array, geospatial, etc

- Conditionals
  - Find users with age between 18 and 30

```
db.users.find({"age": {"$gte":18, "$lte":30}})
```

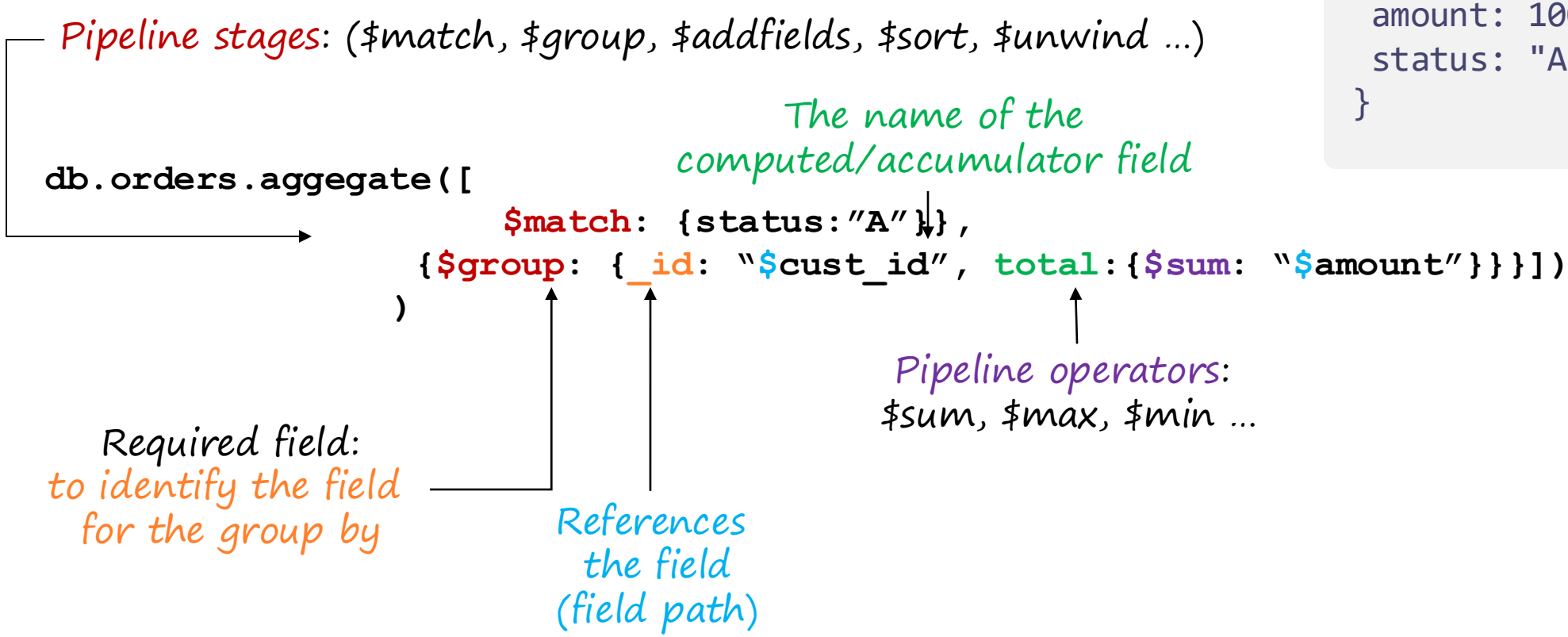
  - Also available `$lt`, `$lte` and `$gt`
- OR query (`$or`/`$in`/`$nin`)

```
db.users.find({"user_id": {"$nin":[12345,"joe"]}})
db.users.find({"$or": [{"age":18}, {"winner":true}]})
```

Aggregation Framework (Pipeline)

Document: Customer

```
{
 cust_id:"A123",
 amount: 100,
 status: "A"
}
```



Documentation: https://docs.mongodb.com/manual/reference/operator/aggregation-pipeline/

Aggregation Framework: Stages

- `$project` – adds or removes attributes for each document
- `$match` – filters the document stream
- `$limit` – passes the first n documents
- `$skip` – skips the first n documents
- `$group` – applies a groupBy function. Returns the grouper field and accumulator fields
- `$sort` – reorders the data pipe
- `$unwind` – deconstructs ana array field and creates a doc for each arr. elem.
- …

Documentation: https://docs.mongodb.org/manual/core/aggregation-introduction/

Geospatial queries

MongoDB Indexes

- `db.users.createIndex({“username”:1})`
- An index can make a dramatic difference in query times
- Indexes are costly: write operations (inserts, update and deletes) that modify an indexed field will take longer
  - In addition to updating the document, MongoDB has to update indexes

- In which field to create an index:
  - What are your frequent queries? Which queries need to be fast?
    - Find a common set of keys from those

- Compound indexes: `db.users.createIndex({“age”:1, “username”:1})`

This sorts by age and then username

Special Indexes

- Geospatial indexes for 2D and shperical geometries
  - `2dsphere` and `2d` indexes

- They work with spherical geometries that model the surface of the earth based on the WGS84 datum (earth as oblate spheroid)

- Distance calculatios using 2dsphere indexes, take the shape of the earth into account and provide a more accurate treatment of distance
  - `2dsphere` allows you to specify geometries for points, lines, polygons in the GeoJSON format.

Geospatial queries

- Perform geospatial operations on MongoDB documents


```
{
  "address": {
     "building": "1007",
     "coord": [-73.856077, 40.848447 ],
     "street": "Morris Park Ave",
     "zipcode": "10462"
  },
  "borough": "Bronx",
  "cuisine": "Bakery",
  "grades": [
     { "date": {"$date": 1393804800000},"grade": "A", "score": 2},
     { "date": {"$date": 1378857600000},"grade": "A", "score": 6},
     { "date": {"$date": 1358985600000},"grade": "A", "score": 10},
     { "date": {"$date": 1322006400000},"grade": "A", "score": 9},
     { "date": {"$date": 1299715200000},"grade": "B", "score": 14}
  ],
  "name": "Morris Park Bake Shop",
  "restaurant_id": "30075445"
}
```

GeoJSON documents

- A JSON standard to represent goespatial data
- To specify GeoJSON data, use an embedded document with two fields:
  - **type**: specifies GeoJSON geometry type
  - **coordinates**: specifies the object's coordinates

```
{
  "name": "Biblioteca Vila de Gracia",
  "type": "library",
  "geometry": {
    "type": "Point",
    "coordinates": [2.158311862578671, 41.401512395604129 ]
  }
}
```

GeoJSON Types

- `Point`

```
{ type: "Point", coordinates: [ 40, 5 ] }
```

- `LineString`

```
{ type: "LineString", coordinates: [ [ 40, 5 ], [ 41, 6 ] ] }
```

- `Polygon`

```
{
  type: "Polygon",
  coordinates: [ [ [ 0 , 0 ] , [ 3 , 6 ] , [ 6 , 1 ] , [ 0 , 0  ] ] ]
}
```

Documentation: https://docs.mongodb.com/manual/reference/geojson/

Geospatial Indexes

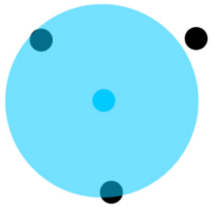
- Used to calculate geometries on earth-like spheres
- A collection **must** have a spatial index before executing geospatial queries
- Creating a `2dsphere` index:

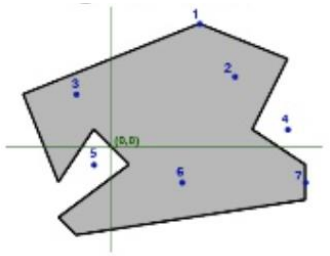
```
> db.collection.createIndex({geometry: "2dsphere"})
```

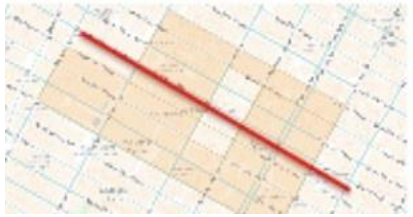
Documentation: https://docs.mongodb.com/manual/core/2dsphere/

Supported geospatial queries

- `$near`
  - Returns documents in proximity to a point
  - Optional: **`$minDistance`** and **`$maxDistance`**
- `$geoWithin`
  - Returns documents withing a specified geometry
- `$geoIntersects`
  - Returns documents that intersect with a specified geometry







Documentation: https://docs.mongodb.com/manual/core/2dsphere/

Example

```
> var barcelona = {
   "type": "Polygon",
    "coordinates": [
   [-73,40],
   [-73.9,40.72],
   …
]}
```

Location field

Find all point, lines and polygon containing documents that have a point in Barcelona

```
db.openStreetMaps.find("geometry":{"$geoIntersects": {"$geometry": barcelona}})
```

$geometry operator

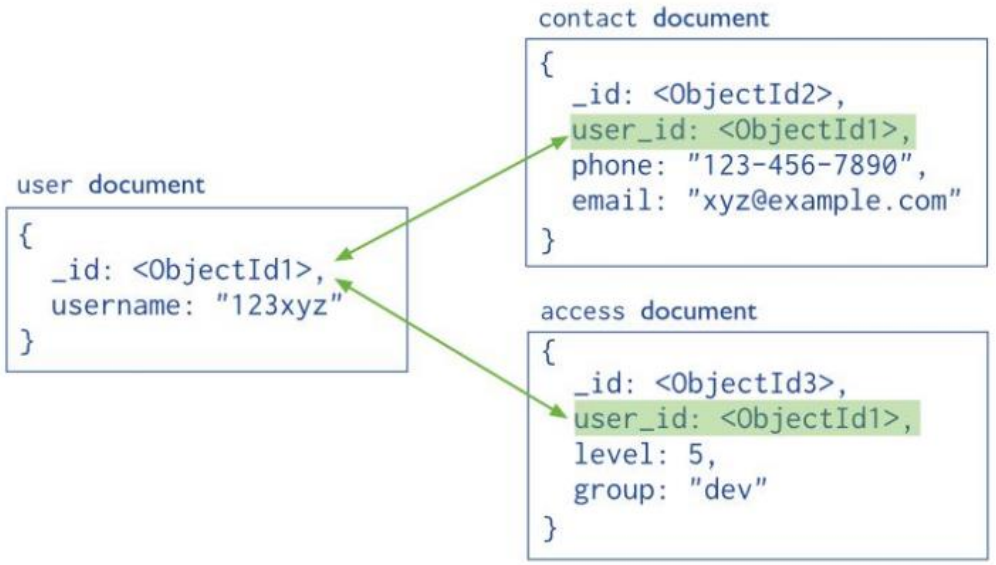
Find all point, lines and polygon containing documents that are completely contained in Barcelona

```
db.openStreetMaps.find("geometry":{"$geoWithin": {"$geometry": barcelona}})
```

Modeling in MongoDB

Modeling with MongoDB

- MongoDB allows different degrees of normalization
- Choice depends on information requirements (i.e., queries)
- Normalized model



Denormalization options

- Embedded documents
  - Simplest way
  - Insert document as sub-document
- Move attrs to the root document
  - All data directly in one document
  - Simpler document structure

```
{
  _id: <ObjectId1>,
  username: "123xyz",
  contact: {
             phone: "123-456-7890",
             email: "xyz@example.com"
           },
  access: {
             level: 5,
             group: "dev"
           }
}
```

Embedded sub-document

Embedded sub-document

```
{
  _id: <ObjectId1>,
  username: “123xyz”,
  contact_phone: “123-456-7890”,
  contact_email: “xyz@example.com”,
  access_level: 5
  access_group: “dev”
}
```

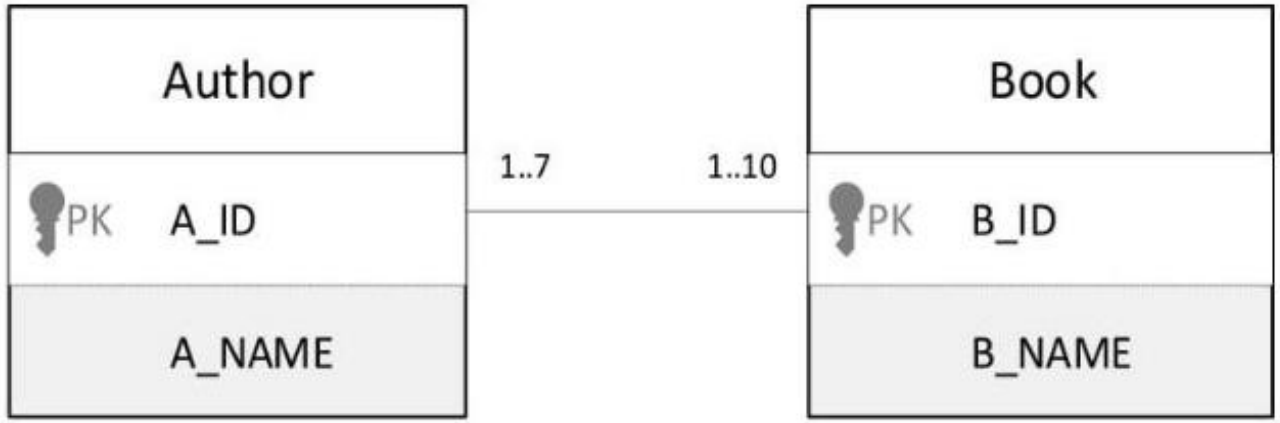
Denormalization options

- Array of nested documents
  - Many sub documents related to root
  - JSON array of documents

```
{
   _id: <ObjectId1>,
   username: “123xyz”,
   contacts: [
                  { type: “work”, phone: “123-456-7890”, email: “xyz@example.com” },
                  { type: “home”, phone: “098-765-4321”, email: “xyz@home.com” },
               ]
   access_level: 5
   access_group: “dev”
}
```

Modeling

- Given the conceptual schema. How many logical designs can you come up with?



#1: Authors nested

```
Books:{
    "B_ID":int,
    "B_NAME": varchar,
    "Authors" : [{
      "A_ID": int,
      "A_NAME": varchar,
    }]}
```

#2: Books nested

```
Authors:{
    "A_ID":int,
    "A_NAME": varchar,
    "Books" : [{
      "B_ID": int,
      "B_NAME": varchar,
    }]}
```

#3: Both nested

```
Books:{
    "B_ID":int,
    "B_NAME": varchar,
    "Authors" : [{
      "A_ID": int,
      "A_NAME": varchar,
    }]}
Authors:{
    "A_ID":int,
    "A_NAME": varchar,
    "Books" : [{
      "B_ID": int,
      "B_NAME": varchar,
    }]}
```

#4: Authors referred

```
Books:{
    "B_ID":int,
    "B_NAME": varchar,
    "Authors" : ["A_ID": int]
    },
Authors:{
    "A_ID":int,
    "A_NAME": varchar
    }
```

#5: Books referred

```
Authors:{
    "A_ID":int,
    "A_NAME": varchar,
    "Books" : ["B_ID": int]
    },
Books:{
    "B_ID":int,
    "B_NAME": varchar,
    }
```

#6: Both referred

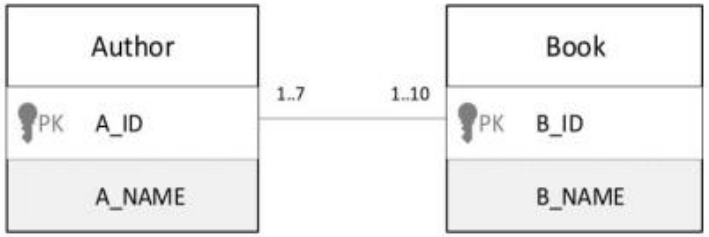
```
Authors:{
    "A_ID":int,
    "A_NAME": varchar,
    "Books": ["B_ID": int]
    },
Books:{
    "B_ID":int,
    "B_NAME": varchar,
    "Authors" : ["A_ID": int]
    }
```

#7: Normalization

```
Authors:{
    "A_ID":int,
    "A_NAME": varchar
    },
Books:{
    "B_ID":int,
    "B_NAME": varchar
    },
Author_Book:{
    "A_ID":int,
    "B_ID": int
    }
```

Which one is better?

Depends on the workload (queries)!



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- Query: Find the book names, given the author identifier.

#1: Authors nested

```
Books:{
    "B_ID":int,
    "B_NAME": varchar,
    "Authors" : [{
      "A_ID": int,
      "A_NAME": varchar,
    }]}
```

#2: Books nested

```
Authors:{
    "A_ID":int,
    "A_NAME": varchar,
    "Books" : [{
      "B_ID": int,
      "B_NAME": varchar,
    }]}
```

#3: Both nested

```
Books:{
    "B_ID":int,
    "B_NAME": varchar,
    "Authors" : [{
      "A_ID": int,
      "A_NAME": varchar,
    }]}
Authors:{
    "A_ID":int,
    "A_NAME": varchar,
    "Books" : [{
      "B_ID": int,
      "B_NAME": varchar,
    }]}
```

#4: Authors referred

```
Books:{
    "B_ID":int,
    "B_NAME": varchar,
    "Authors" : ["A_ID": int]
    },
Authors:{
    "A_ID":int,
    "A_NAME": varchar
    }
```

#5: Books referred

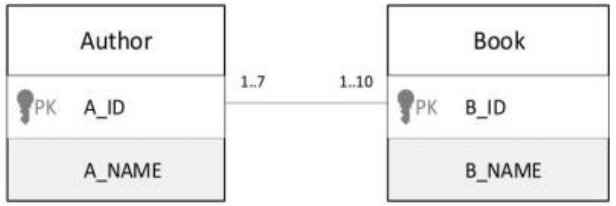
```
Authors:{
    "A_ID":int,
    "A_NAME": varchar,
    "Books" : ["B_ID": int]
    },
Books:{
    "B_ID":int,
    "B_NAME": varchar,
    }
```

#6: Both referred

```
Authors:{
    "A_ID":int,
    "A_NAME": varchar,
    "Books": ["B_ID": int]
    },
Books:{
    "B_ID":int,
    "B_NAME": varchar,
    "Authors" : ["A_ID": int]
    }
```

#7: Normalization

```
Authors:{
    "A_ID":int,
    "A_NAME": varchar
    },
Books:{
    "B_ID":int,
    "B_NAME": varchar
    },
Author_Book:{
    "A_ID":int,
    "B_ID": int
    }
```



MongoDB Python API

- Pymongo – Python driver for MongoDB

```
from pymongo import MongoClient
client = MongoClient('127.0.0.1:27017')
db = client['test']
collection = db.create_collection('example')
```

- Create object

```
d = {"x":1, "y":"foo"}
db.collection.insert_one(d)

for doc in db.collection.find({}):
   print(doc)
```

Closing

- MongoDB Tools
  - Community Server
  - Mongo Shell
  - MongoDB Compass
  - MongoDB command line tools
- Querying in MongoDB
- Geospatial data
- Modeling data in MongoDB

References

- K. Chodorow, M. Dirolf. MongoDB: The Definitive Guide, O'Reilly Media 1st edition (2010)
- MongoDB Manual
  - https://docs.mongodb.org/manual/
- Getting Started with MongoDB (Java)
  - https://docs.mongodb.org/getting-started/java/