# Web Application Development

COMP4347

COMP5347

## Connecting to MongoDB

Week 7

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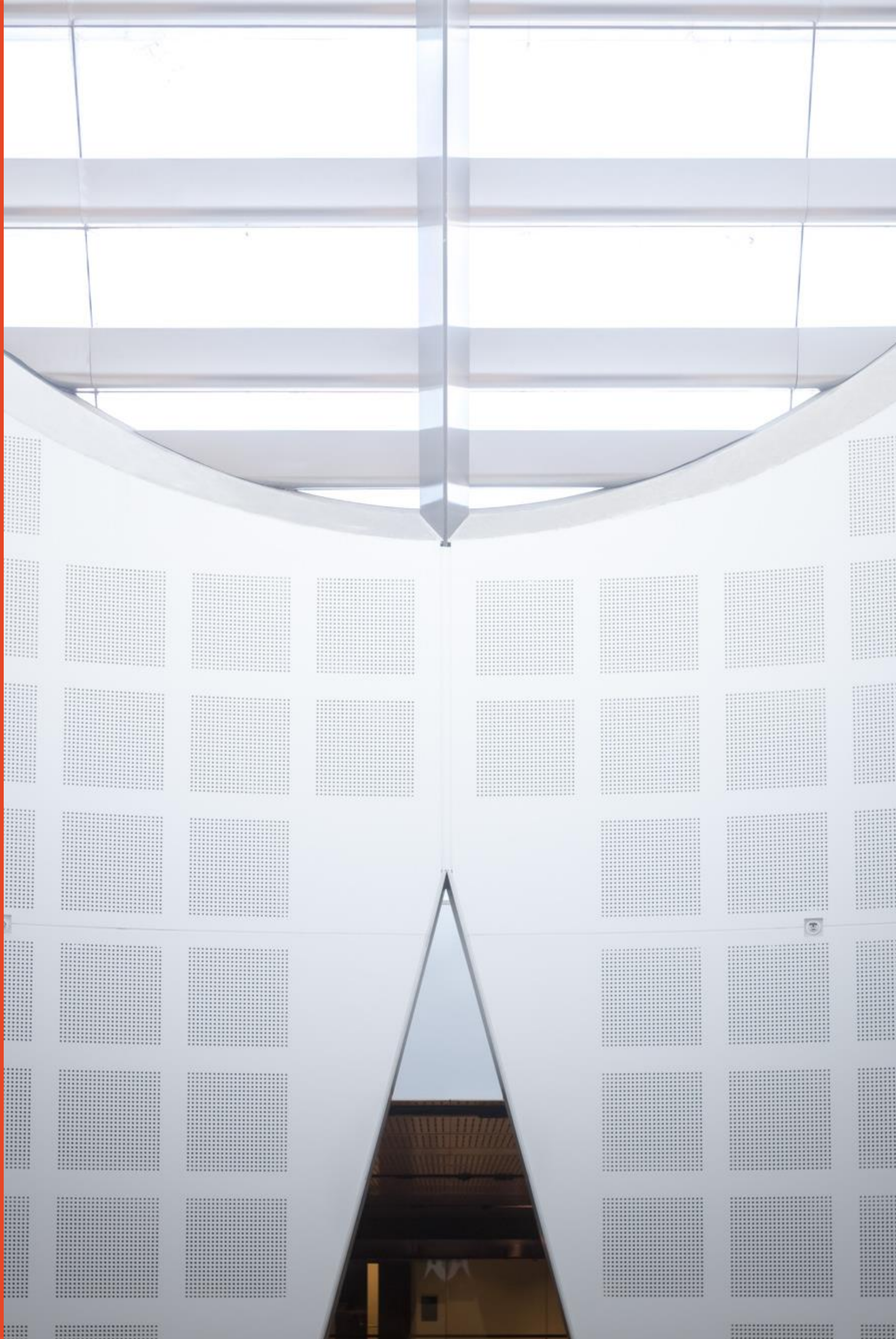


## Outline

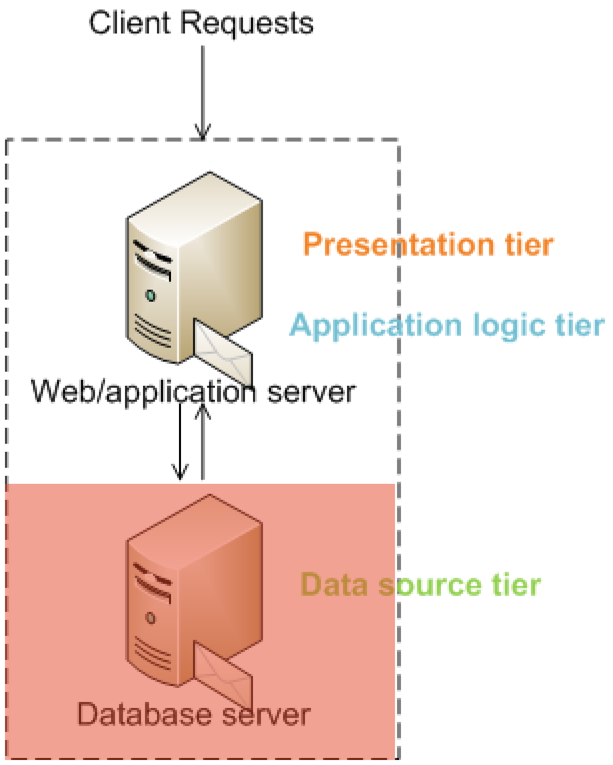
- MongoDB indexing
- Database
  - Data layer (MVC)
- Mongoose
  - Schema, Model, Document
  - Mongoose queries
  - Database connection management

## Databases Layer/Tier

- Database tier in Multi-tier (n-tier) Architecture
  - Maintain persistent data of the application
  - CRUD operations (Create, Read, Update, Delete)

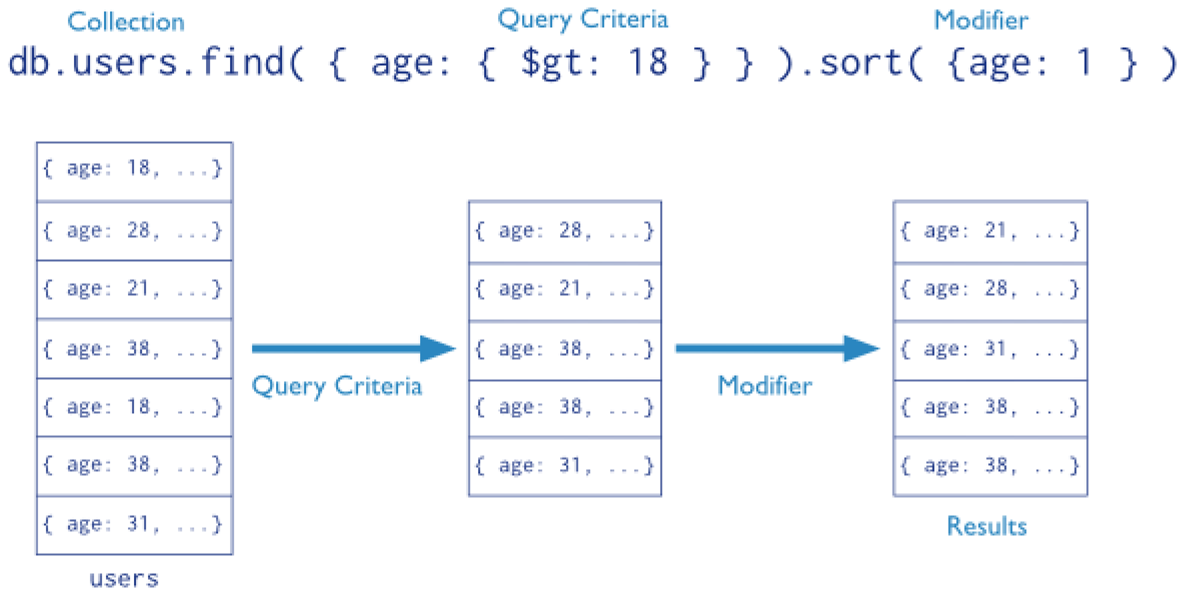
- Request/query processing require network communication and server processing

- Many ways to improve performance
  - Hardware
  - Software/application
    - Database level



## MongoDB Queries

Find documents in the **users** collection with **age** field greater than 18, sort the results in ascending order by **age**



- Creating an appropriate index can help to limit the number of documents it must read

## Database Indexes and Efficiency

- Consider the worst-case scenario for searching where we compare a query against every single record. If there are n elements, it takes O(n) time to do a search.
- In comparison, a balanced binary tree data structure can be searched in O(log2 n) time.
- It is possible to achieve O(1) search speed
  - one operation to find the result with a hash table data structure.
- No matter which data structure is used, the application of that structure to ensure results are quickly accessible is called an index.

## Indexing

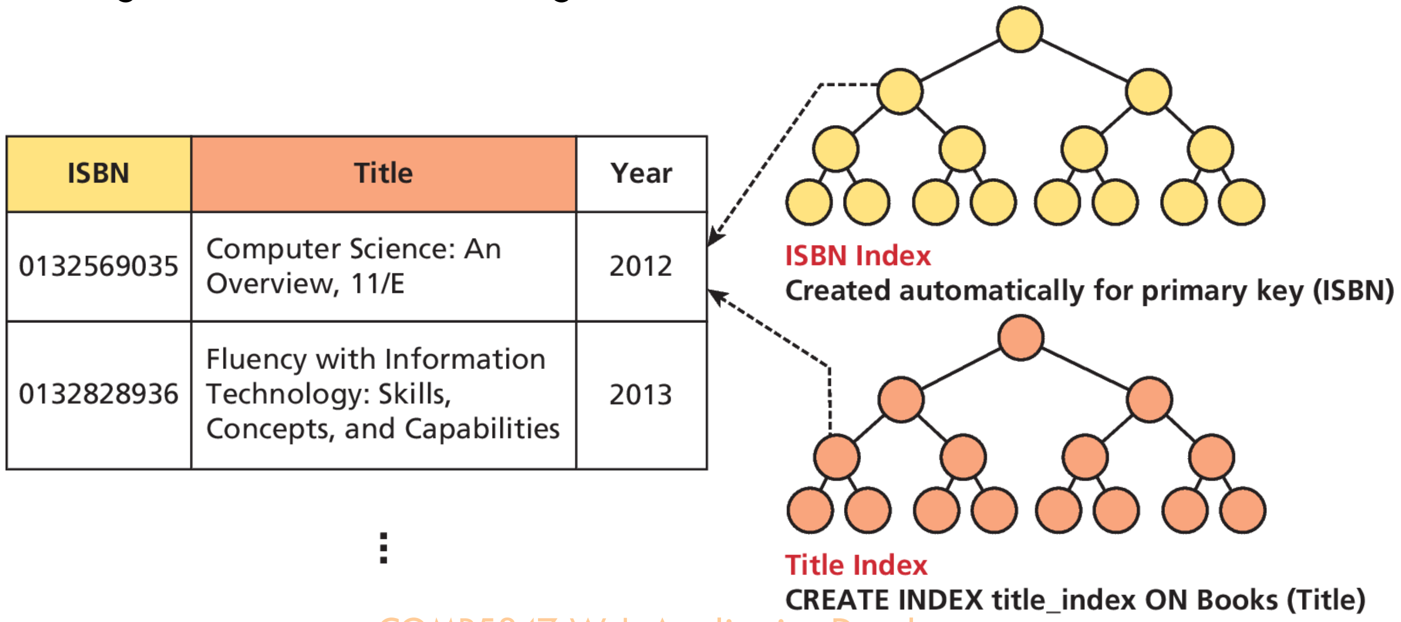
- An index is a data structure that makes it efficient to find certain rows/documents in a table/collection
- Indexes support efficient query execution
- Indexing can help to improve database performance if it is done properly
- Most DBMS providers provide facility for indexing

# Indexing

- An index consists of records (called *index entries*) each of which has a value for the attribute(s)

| | |
|---|---|
| attr. value | Pointer to data record |

- Index files are typically much smaller than the original file
- Most MongoDB indexes are organized as **`B-Tree`** structure



| ISBN | Title | Year |
|---|---|---|
| 0132569035 | Computer Science: An Overview, 11/E | 2012 |
| 0132828936 | Fluency with Information Technology: Skills, Concepts, and Capabilities | 2013 |

⋮

ISBN Index
Created automatically for primary key (ISBN)
Title Index
CREATE INDEX title_index ON Books (Title)

## MongoDB Indexes

- The `_id` index
  - `_id` field is automatically indexed for all collections
  - The `_id` index enforces uniqueness for its keys

- The _id index cannot be dropped

- If you do not use the _id as a key, your application must maintain unique values in the _id field

https://docs.mongodb.com/manual/indexes/

## MongoDB Indexes – Single Field Index

- Single-field index
  - An index that can be created on a single field of a document
  - Additional properties can be specified for an index:
    - Sparse: an index only contain entries that have the indexed field
    - Unique: MongoDB rejects duplicate values for the indexed field

https://docs.mongodb.com/manual/indexes/

## MongoDB – Creating Indexes

- Generic format for creating an index in MongoDB

```
db.<collectionName>.createIndex({<fieldName>:direction})
```

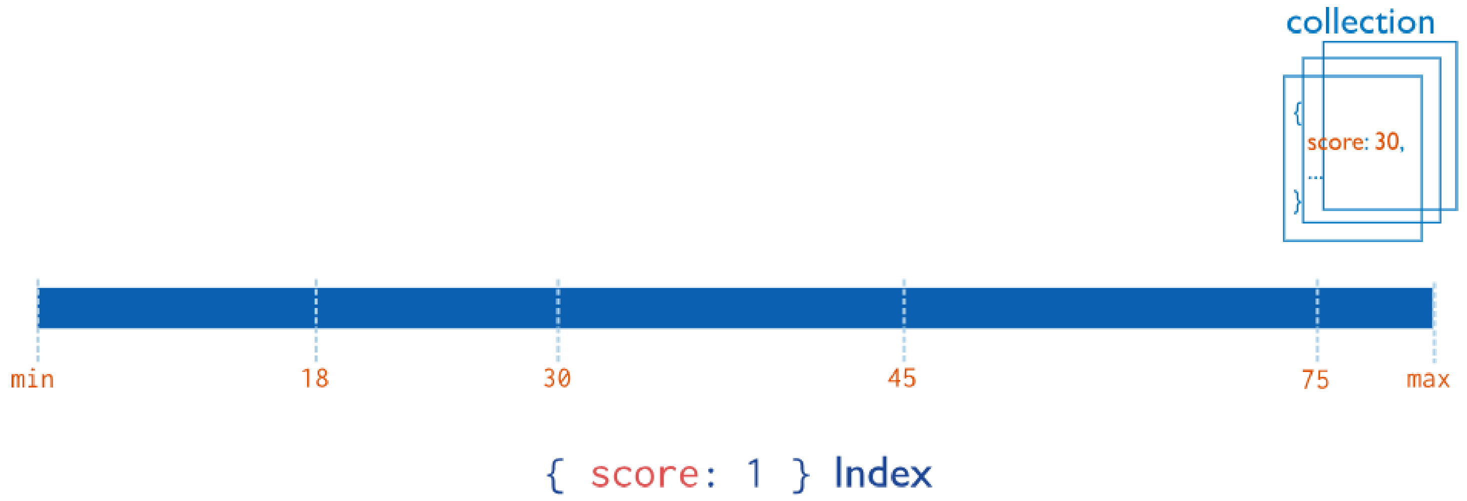
- **fieldName** can be a simple field, array field or field of an embedded document (using dot notation)
- **direction** specifies the direction of the index (1: ascending; -1: descending)

- Examples:
  - db.blog.createIndex({author:1})
  - db.blog.createIndex({tags:-1})
  - db.blog.createIndex({"comments.author":1})

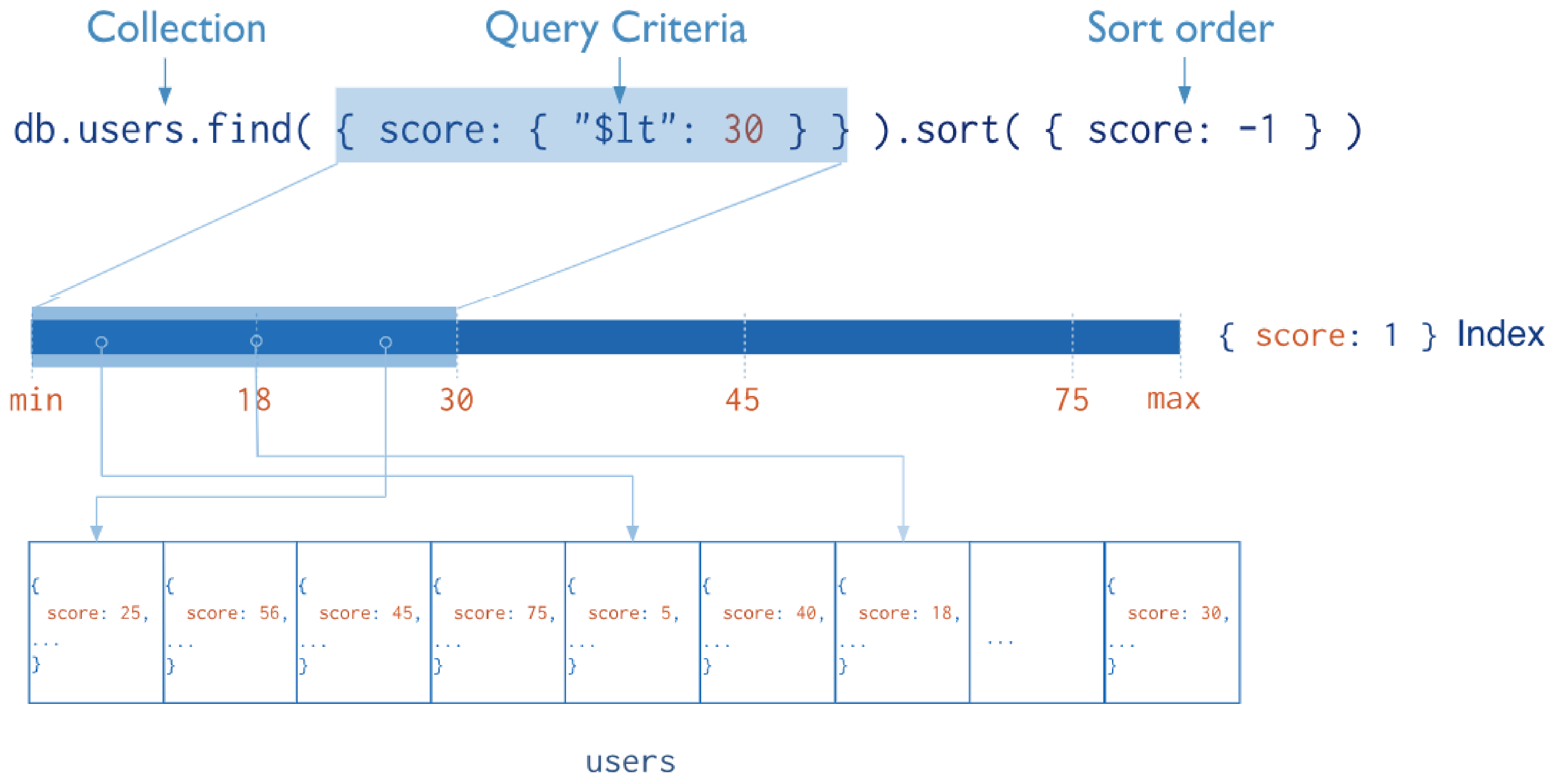
https://docs.mongodb.com/manual/indexes/

## Single Field Index – Example

db.*users*.createIndex({score:1})



# Single Field Index – Example



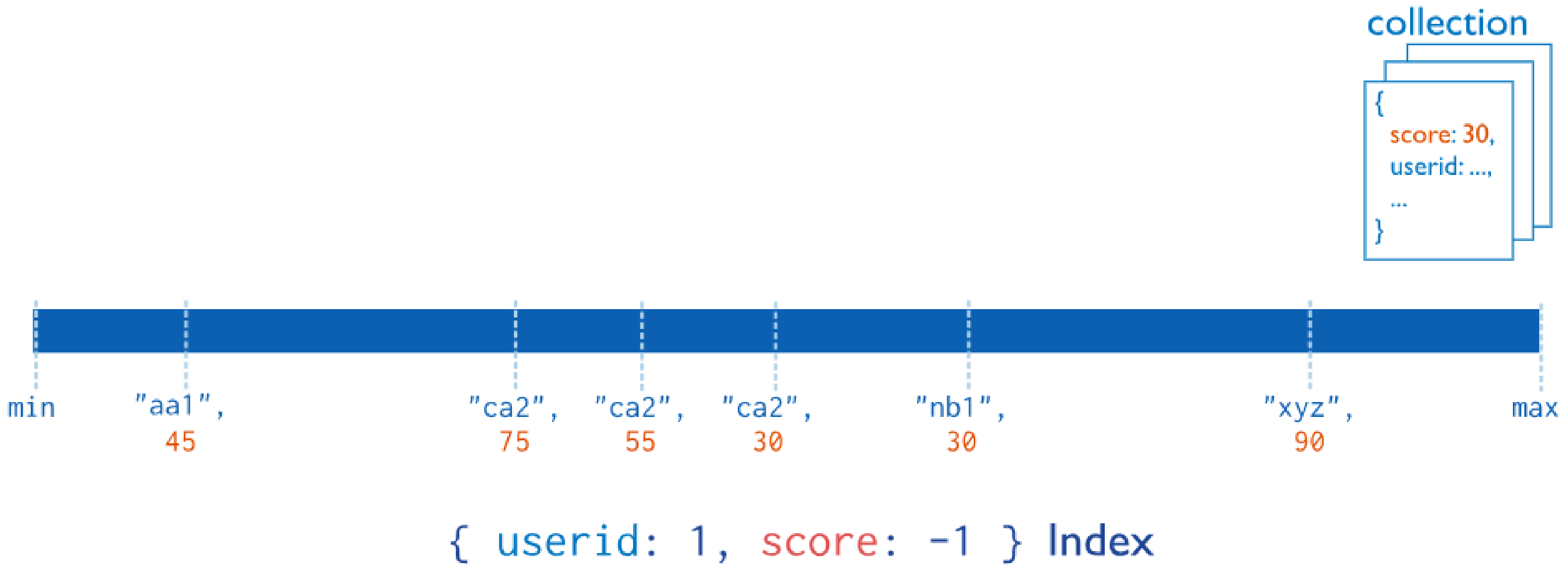
## MongoDB – Compound Index

- Compound index is a single index structure that holds references to multiple fields within a collection

- The order of field in a compound index is very important
  - The indexes are sorted by the value of the first field, then second, third…
  - It supports queries like
    - db.users.find({userid: "ca2", score: {$gt:30} })
    - db.users.find({userid: "ca2"})

## Compound Index – Example

db.creatIndex({userid: 1, score: -1})



## Designing Indexes

- Understand the application requirements and queries
- Identify types of queries that need to be issued to the database
  - Frequency of key queries
  - Read/write and performance implications
  - Available memory on your server
  - Compare and prioritize – trade-off analysis
- Performance profiling
  - Experiment with a variety of index configurations with data sets
  - Choose the best configuration
- Review indexes on regular basis

## Outline

- MongoDB indexing
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  - Data layer (MVC)
- Mongoose
  - Schema, Model, Document
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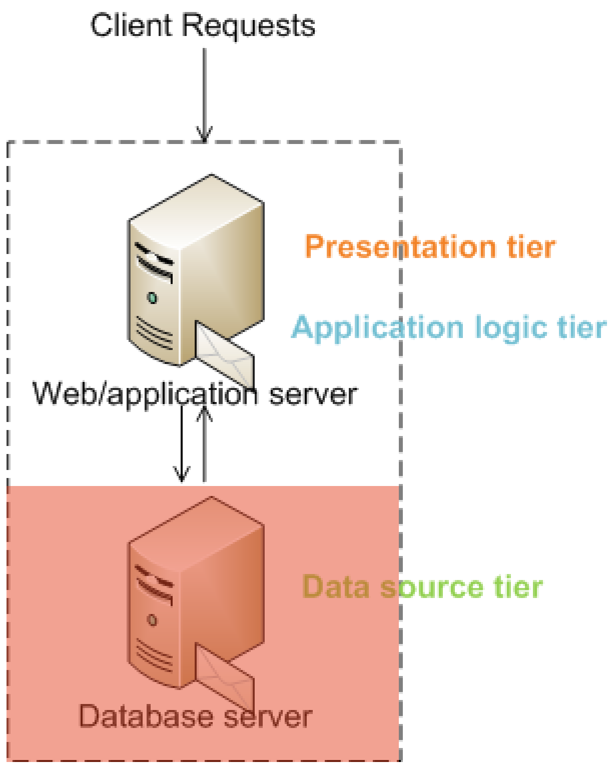
  - Database connection management

## Web Applications – Database

- Database tier in Multi-tier (n-tier) application Architecture
  - Maintain persistent data of the application
  - CRUD operations (Create, Read, Update, Delete)

- Database Server / DBMS
  - RDBMS (MySQL, PostgreSQL)
  - NoSQL DBMS (MongoDB, Redis)
  - Choice of DBMS is crucial

- Express integrates with many DBMS
  - MySQL, PostgreSQL, MongoDB, Redis, many other*



https://expressjs.com/en/guide/database-integration.html

## Why ( and Why Not) Choose NoSQL?

- NoSQL databases rely on a different set of ideas for data modeling that put fast retrieval ahead of other considerations like consistency.
- NoSQL systems handle huge datasets better than relational systems.
- NoSQL databases aren't the best answer for all scenarios.
  - SQL databases use schemas for a very good reason: they ensure data consistency and data integrity.
  - The data in most NoSQL database systems is identified by a unique key. The key-value organization often results in faster retrieval of data in comparison to a relational database
  - Systems like DynamoDB, Firebase, and MongoDB now power thousands of sites including household names like Netflix, eBay, Instagram, Forbes, Facebook, and others.

## Designing Data Access

- Database details such as connection strings and table and field names are examples of externalities.
  - These details tend to change over the life of a web application.
- One simple step might be to extract all database access into separate functions or classes and use those instead.

## Database Drivers

- All database management systems work like a "server" application
  - Running on a host and waiting for connections from clients
    - Simple command line shell client
    - GUI shell client
    - Program-based client
  - There are different protocols db server used to communicate with their clients

- All database management systems provide languagebased drivers to allow developers to write client in various languages
  - Open/close connection to database
  - Translate between language specific construct (functions, methods) and DB queries
  - Translate between language specific data types and database defined data types

- MongoDB provides many native drivers:
  - https://docs.mongodb.com/ecosystem/drivers/

## Higher level module/package

- The native DB drivers provide basic supports for client-side programming
  - Powerful, flexible
  - But usually not easy to use

- Higher level modules usually provide more convenient ways to communicate with DB servers
  - *Mongooes* is the node.js module built on top of basic mongoDB Node.js driver
    - Data structure to match collection “schema”
    - Validation mechanism
    - Connection management

## Object Data Model / Object Relational Model

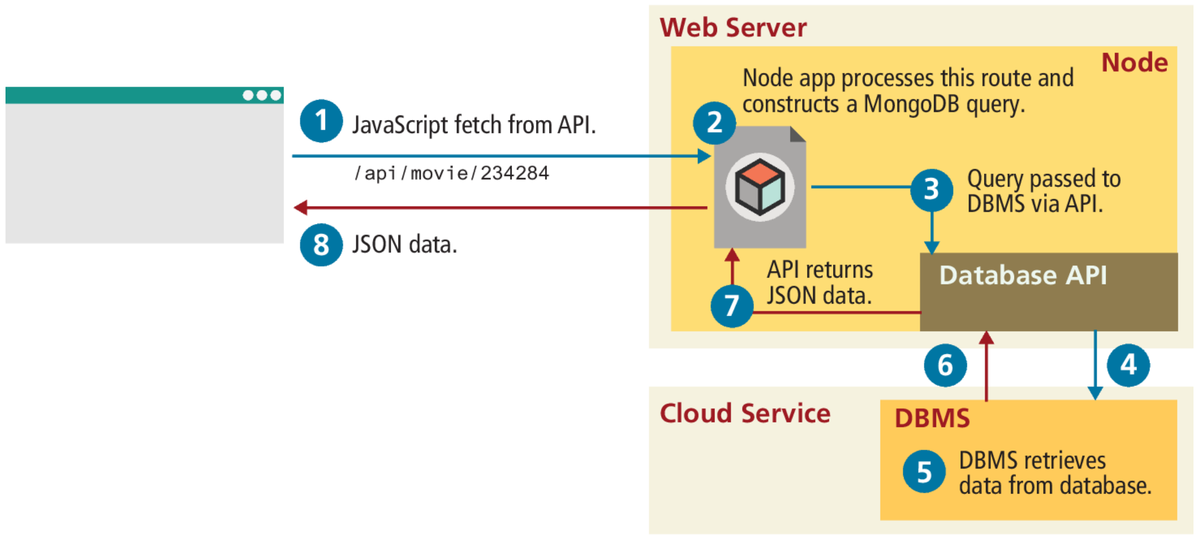
- Approaches to interact with a database
  - Database native query language
    - Structured Query Language (SQL)
    - MongoDB Query Language (MQL)
  - Object Data Model (ODM) / Object Relational Model (ORM)

- Represents the web application data as objects, to be mapped to the DB
  - Productivity
  - Performance

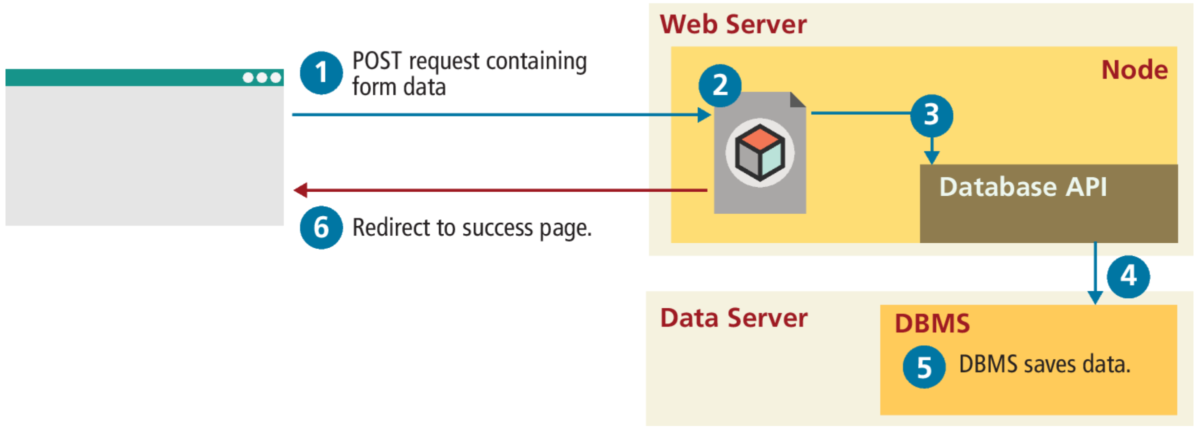
- Node.js supports many ODM/ORM solutions*
  - Mongoose: a MongoDB object modeling tool for asynchronous environment
  - Others; Sequellize, Objection, Waterline
  - Consider features supported, and the community activity
  - Mongoose will be used to access data from MongoDB database

https://www.npmjs.com/search?q=keywords:odm

# How websites use databases?

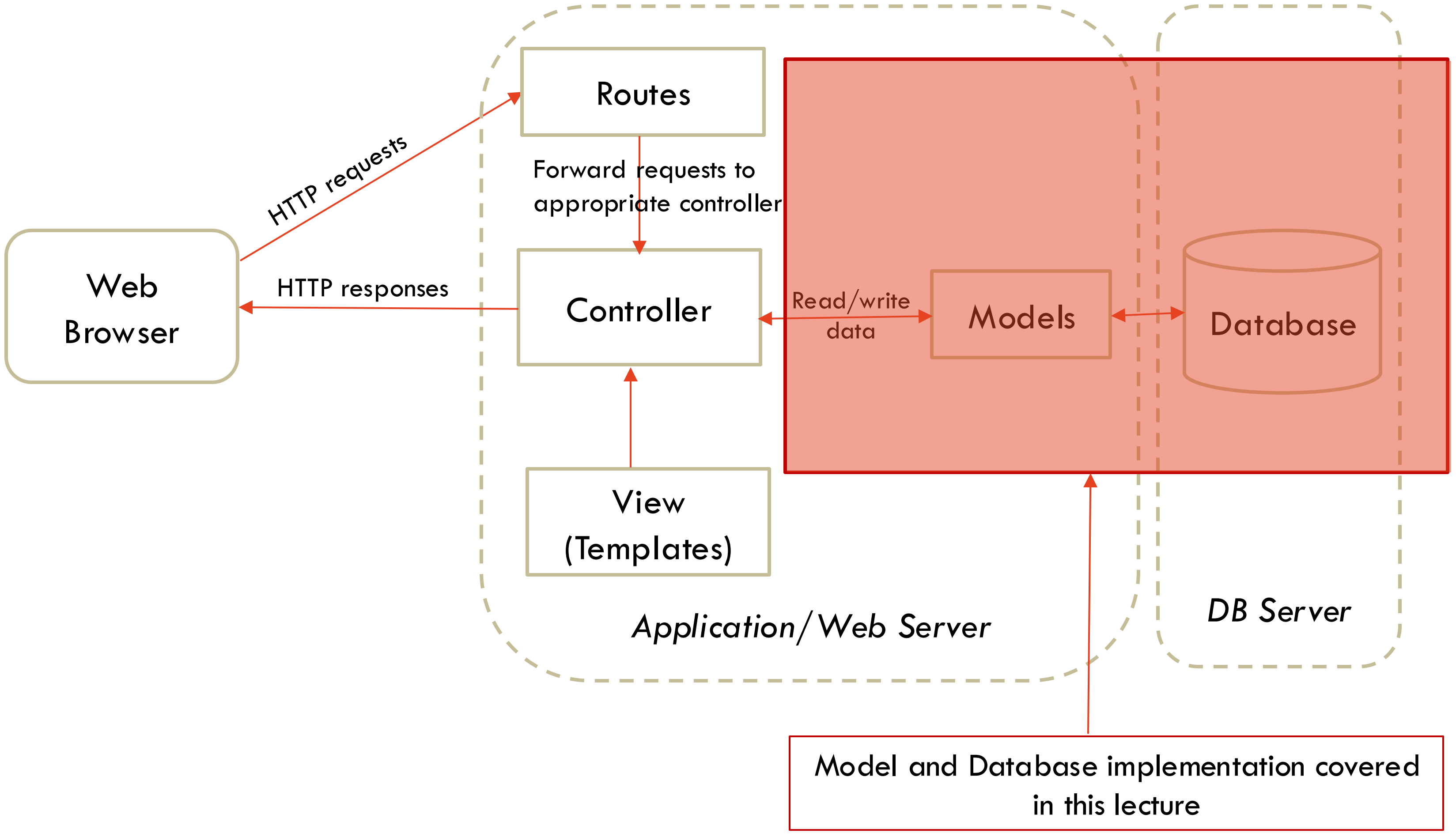


Web Server
Node
Node app processes this route and constructs a MongoDB query.
1 JavaScript fetch from API.
/api/movie/234284
2
3 Query passed to DBMS via API.
8 JSON data.
7 API returns JSON data.
Database API
6
4
Cloud Service
DBMS
5 DBMS retrieves data from database.



Web Server
Node
1 POST request containing form data
2
3
Database API
6 Redirect to success page.
4
Data Server
DBMS
5 DBMS saves data.

## MVC Application Architecture



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  - Database connection management

## Mongoose

- All database operations should be implemented using event-driven programming style
  - Start an operation
  - Register a *callback* function to indicate what we want to do when the operation completes
  - Continue processing other parts of the program

## Mongoose – Basic Concepts

- Schema
  - Schema is an *abstract* data structure defines the shape of the documents in a collection
  - Each name/value pair is a path
- Model
  - Model is a compiled version of schema, model is the schema binded with a collection
- Document
  - Document is an instance of Model, mapped to the actual document in a collection

## Mongoose – Schema, Model and Document

- A collection “**movies**” with the example document

```
{   "_id" : 1,
   "Title" : "Sense and Sensibility",
    "Year" : 1995,
     "Genres" : [ "Comedy", "Drama",
“Romance”]
}
```

- Schema definition

```
var movieSchema = new Schema({
  Title: String,
   Year: Number,
  Genres: [String]
})
```

- Model definition (<ModelName>, <schema>)
  - Mongoose will automatically create a **collection** using the mode name (lowercase + pluralized) in your MongoDB.

```
var Movie = mongooes.model(‘Movie’,
movieSchema, ‘movies’)
```

- Save a document in a movie collection

```
var aMovie = new Movie({
    title=“Ride With the Devil”})
```

## Mongoose – Queries

- All Mongodb queries run on a model
  - Including `find`, `update`, `aggregate`
  - Very similar syntax to the shell command query
  - A callback function needs to be specified if we want to do something with the query result
  - Two ways to run the callback function
    - Callback function is passed as a *parameter* in the query
      - The operation will be executed immediately with results passed to the callback
    - Callback function is not passed as a parameter in the query
      - An instance of the query is returned which provides a special query builder interface

## Queries with Callback Function

```
Movie.find({}, function(err,movies){
    if (err){
     console.log("Query error!")
    }else{
       console.log(movies)
    }
  }
)
```

Call back function

- The query was executed immediately, and the results passed to the callback
  - Callback syntax in Mongoose: **callback (error, results)**
  - If successful, results will be populated with the query results, error will be null
  - If unsuccessful error will contain error document and the result will be null
  - Result depends on the operations: e.g., find() list of documents, count() number of documents, update() the number of documents affected

## Query Instance – No Callback Passed

- A Query instance enables you to build up a query using chaining syntax, rather than specifying JSON object
  - A full list of Query helper functions (https://mongoosejs.com/docs/api/query.html)

```
Movie.find({Year: 1996})
.select({Title:1,Year:1})
.exec(function(err,movies){
  if (err){
    console.log("Query error!")
  }else{
    console.log("Movies in year 1996:")
    console.log(movies)
  }
 }
)
```

## Query Instance – No Callback Passed

- A Query instance enables you to build up a query using chaining syntax, rather than specifying JSON object
  - A full list of Query helper functions (https://mongoosejs.com/docs/api/query.html)

```
Var query = Movie.find({Year: 1996});
query.select({Title:1,Year:1});

query.exec(function(err,movies){
  if (err){
    console.log("Query error!")
  }else{
    console.log("Movies in year 1996:")
    console.log(movies)
  }
 }
)
```

## Queries – Insert Documents

- First create a document based on the model
- Use *save()* method to insert the new document
  - The model is linked to the collection, so it knows which collection to save this document to

```
var aMovie = new Movie(
{ MovieID: 292,
  Title: "Outbreak",
  Year: 1995,
  Genres: ['Action','Drama','Sci-Fi','Thriller']}
)
aMovie.save()
```

## Queries – Static Methods

- To run certain queries often on some collection, we can implement those queries either as *static methods* or as *instance methods*

- *A static method* is defined on the Model (collection), any standard query/aggregation can be implemented as static method

- Better for reusability and modularity of database related code

- Define static methods via the `.statics` property of a schema **before compiling the model.**

## Static Methods – Example

```
movieSchema.statics.findByYear = function(year, callback){
    return this
             .find({Year: year})
             .select({Title:1,Year:1})
             .exec(callback)
}
var Movie = mongoose.model('Movie', movieSchema, ‘movies’)
Movie.findByYear(1995, function(err,movies){
       if (err){
        console.log("Query error!")
       }else{
          console.log("Movies in year 1995:")
          console.log(movies)
       }
})
```

**this** keyword refers to the current model that calls the method

We call the method on **Movie** model, **this** refers to Movie model, which represent the movies collection.

The call becomes:

```
Movie
.find(…)
.select(…)
.exec(callback)
```

A callback function is always supplied when we make the call, instead of predefined.

## Query – Instance Methods

- An **instance method** is a function you define on **individual documents**, meaning you call it on an object retrieved from the database (not on the model class).

- Instance methods is defined on document instance

- It is often used to create queries based on a given document

- Define it by adding `.methods` property of your schema

## Instance Methods

```
movieSchema.methods.findSimilarYear = function(cb) {
  return this.model('Movie').find({ Year: this.Year }, callback);
};

var aMovie = new Movie(
{MovieID: 292,
 Title: "Outbreak",
 Year: 1995,
 Genres: ['Action','Drama','Sci-Fi','Thriller']}
)
aMovie.findSimilarYear(function(err,movies){
  if (err){
    console.log("Query error!")
  }else{
    console.log("The movies released in the same year as " +
        newMovie.Title + " are:")
    console.log(movies)
 }
}
)
```

**this** keyword refers to the current document that calls the method, we can use it to access the model and individual property of the document

Instance methods are called on document instance

## Database Connection

- Opening and closing connection to database is time consuming
- Let all requests share a pool of connections and only close them when application shuts down
- Mongoose manages connection pool

http://mongoosejs.com/docs/connections.html

## Database Connection

– No application level open or close is required

– Mongoose.connect() prepares a number of connections. The callback can handle the success/error

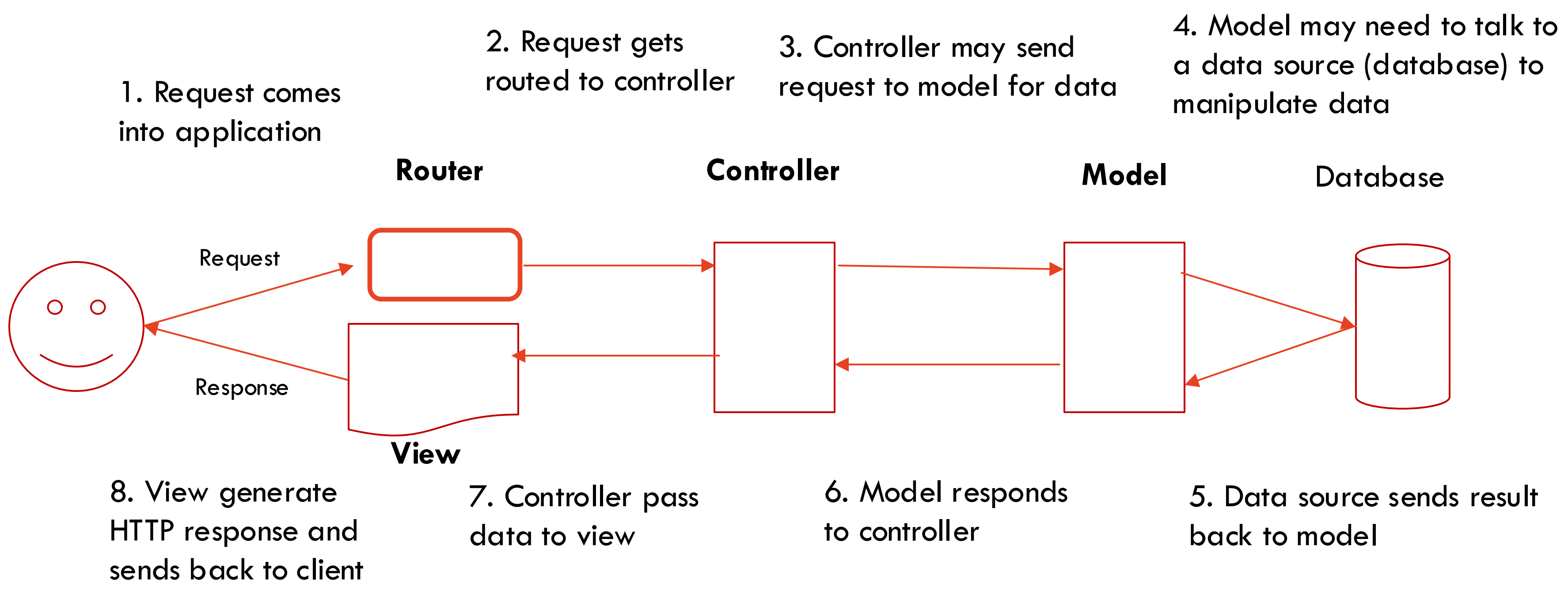
```
var mongoose = require('mongoose')

mongoose.connect('mongodb://localhost/comp5347', function
(err) {
  if (!err)
      console.log('mongodb connected')
})
```

Connection string or database URI

- You can specify more parameters, e.g., mongoose.connect('mongodb://username:password@host:port/database?options...');

http://mongoosejs.com/docs/connections.html

# Full MVC Architecture



1. Request comes into application
2. Request gets routed to controller
3. Controller may send request to model for data
4. Model may need to talk to a data source (database) to manipulate data
Router
Controller
Model
Database
Request
Response
View
8. View generate HTTP response and sends back to client
7. Controller pass data to view
6. Model responds to controller
5. Data source sends result back to model

- Database related code should be put in model layer
- Controller should not have knowledge about the actual database
- Modularity allows easy switching between technologies
  - e.g. different view templates, different database management systems

## Resources

- Haviv, Amos Q, MEAN Web Development

- MongoDB online documents:
  - MongoDB CRUD Operations
    - http://docs.mongodb.org/manual/core/crud-introduction/

- Mongooes online documents:
  - Guide: http://mongoosejs.com/docs/guide.html

# W7 Tutorial: MongoDB
# W8 Tutorial: Mongoose + Promise
# W8 Lecture: Client-side Libraries

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