Web Application Development

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WAD 2020 Lecture Notes – #4 «Databases»

Databases

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SKEWL

!?

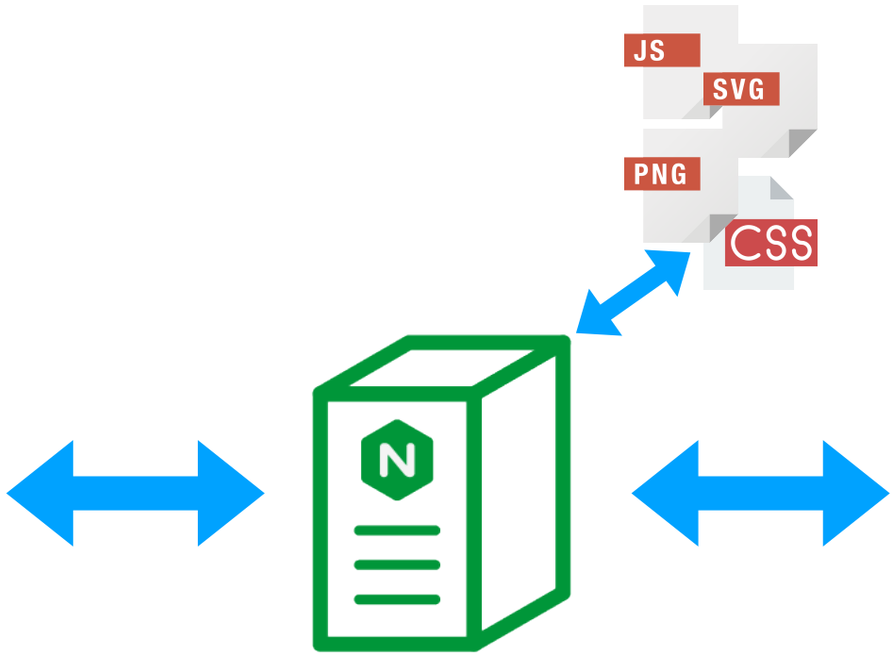
Quiz time

https://quiz.itmo.xyz/

Database

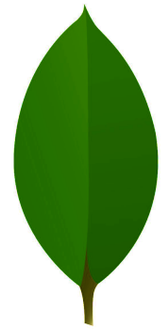
Web Application Architecture

Web browser



Nginx

Flask



MongoDB Database

NoSQL Databases

⚠️ Caution! Different terminology

- **Document databases**
- **Key-value databases**
- Wide-column stores
- Graph databases

MongoDB Features

- Rich query language (CRUD, aggregate, text search, geospatial)
- High availability (replication, automatic failover, data redundancy)
- Horizontal scalability (sharding data)
- Multiple storage engines (file, encryption, in-memory)

JSON

Data types:

- String
- Number (int, float)
- Object (nested JSON)
- Array
- Boolean
- null

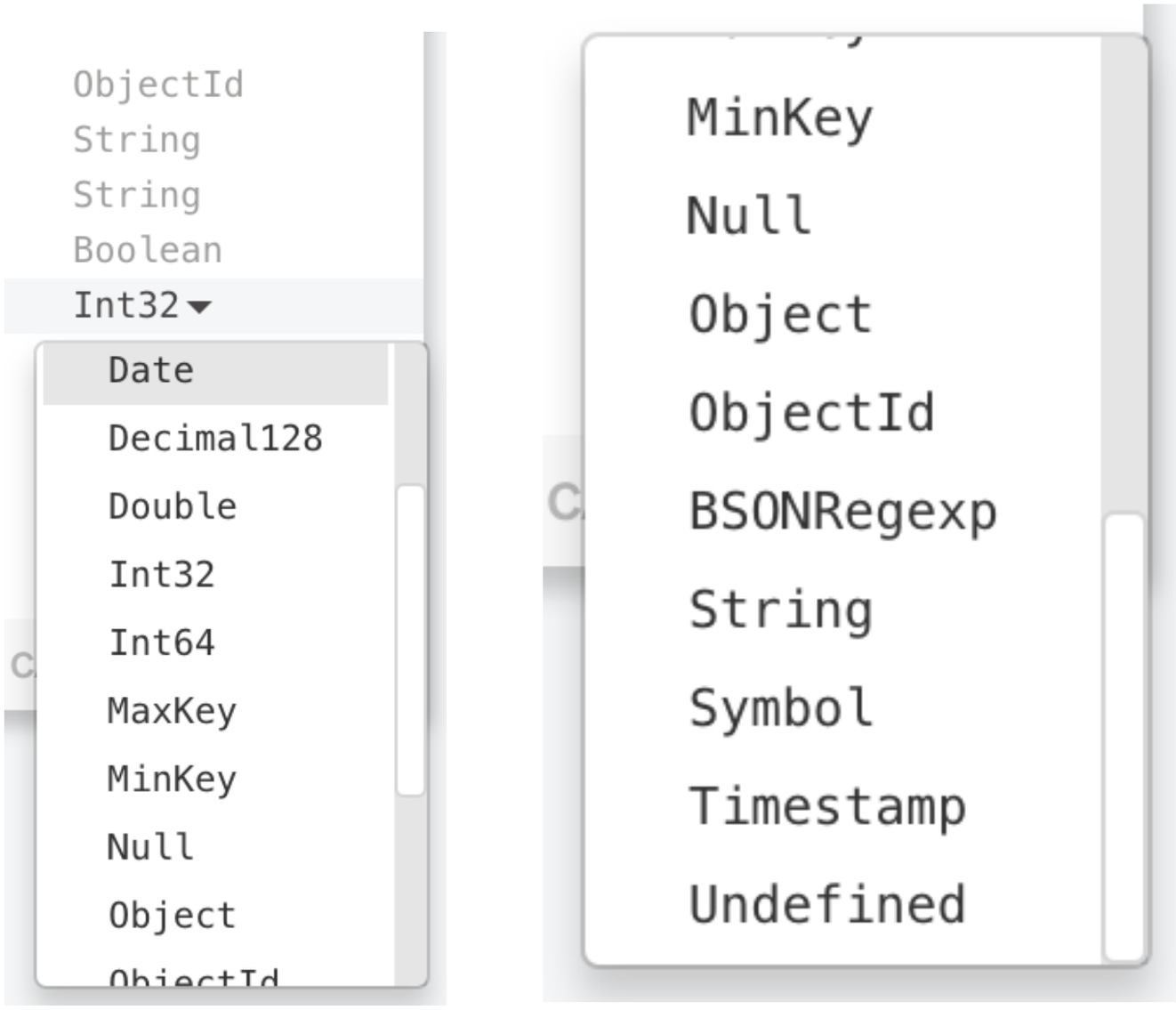
```json
{
  "firstName": "John",
  "lastName": "Smith",
  "isAlive": true,
  "age": 27,
  "address": {
    "streetAddress": "21 2nd Street",
    "city": "New York",
    "state": "NY",
    "postalCode": "10021-3100"
  },
  "phoneNumbers": [
    {
      "type": "home",
      "number": "212 555-1234"
    },
    {
      "type": "office",
      "number": "646 555-4567"
    }
  ],
  "children": [],
  "spouse": null
}
```

JSON representation

firstName	John	String
lastName	Smith	String
isAlive	true	Boolean
age	27	Int32
▼ address	{ 4 fields }	Object
streetAddress	21 2nd Street	String
city	New York	String
state	NY	String
postalCode	10021-3100	String
▼ phoneNumbers	[2 elements]	Array
▼ [0]	{ 2 fields }	Object
type	home	String
number	212 555-1234	String
▼ [1]	{ 2 fields }	Object
type	office	String
number	646 555-4567	String
▼ children	[0 elements]	Array
spouse	null	Null

BSON

- Binary
- Strictly typed
- Similar to JSON



Database & collection

```
{
    "_id" : ObjectId("5e9975a7e8de390f5968e28d"),
    "username" : "user",
    "password" : "123456",
    "registerDate" : ISODate("2020-04-18T12:00:00.000Z")
}
{
    "_id" : ObjectId("5e9975a7e8de390f5968e28d"),
    "username" : "user",
    "password" : "123456",
    "registerDate" : ISODate("2020-04-18T12:00:00.000Z")
}
```

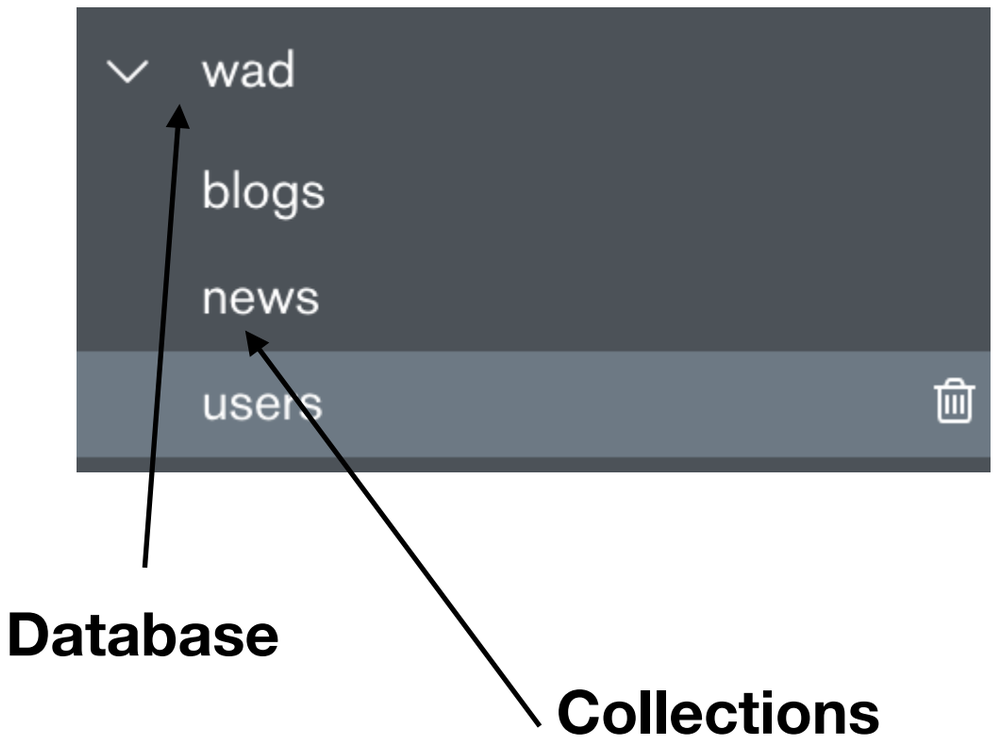
```
{
    "_id" : ObjectId("5e9975a7e8de390f5968e28d"),
    "title" : "First article",
    "publishDate" : ISODate("2020-04-18T12:00:00.000Z")
}
```

***

***

***

Database & collection



Documents

```
_id: ObjectId("5e9975a7e8de390f5968e28d")
username: "user"
password: "123456"
registerDate: 2020-04-18T12:00:00.000+00:00
```

```
1   _id: ObjectId("5e9976a42482b3456c1dc4f6")
2   firstName : "John "
3   lastName : "Smith "
4   isAlive : true
5   age : 27
6 › address : Object
7 › phoneNumbers : Array
8 › children : Array
9   spouse : null
```

Key-value

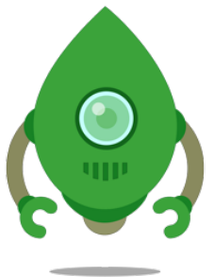
Limitations:

- Key cannot include: **null**, **$**, **.**
- Nested depth **100**
- Case insensitive db names
- Document size 16mb

Database operations

Access via:

- Command line interface (CLI)



- Visual (Compass, Robo 3T)
- Program (pymongo, mongoengine)

Operations:

- Insert
- Remove
- Find
- Update

Literature

- Databases and collections: https://docs.mongodb.com/manual/core/databases-and-collections/

- BSON in MongoDB: https://docs.mongodb.com/manual/reference/bson-types/

- Compass: https://www.mongodb.com/products/compass

- Robo 3T: https://robomongo.org/

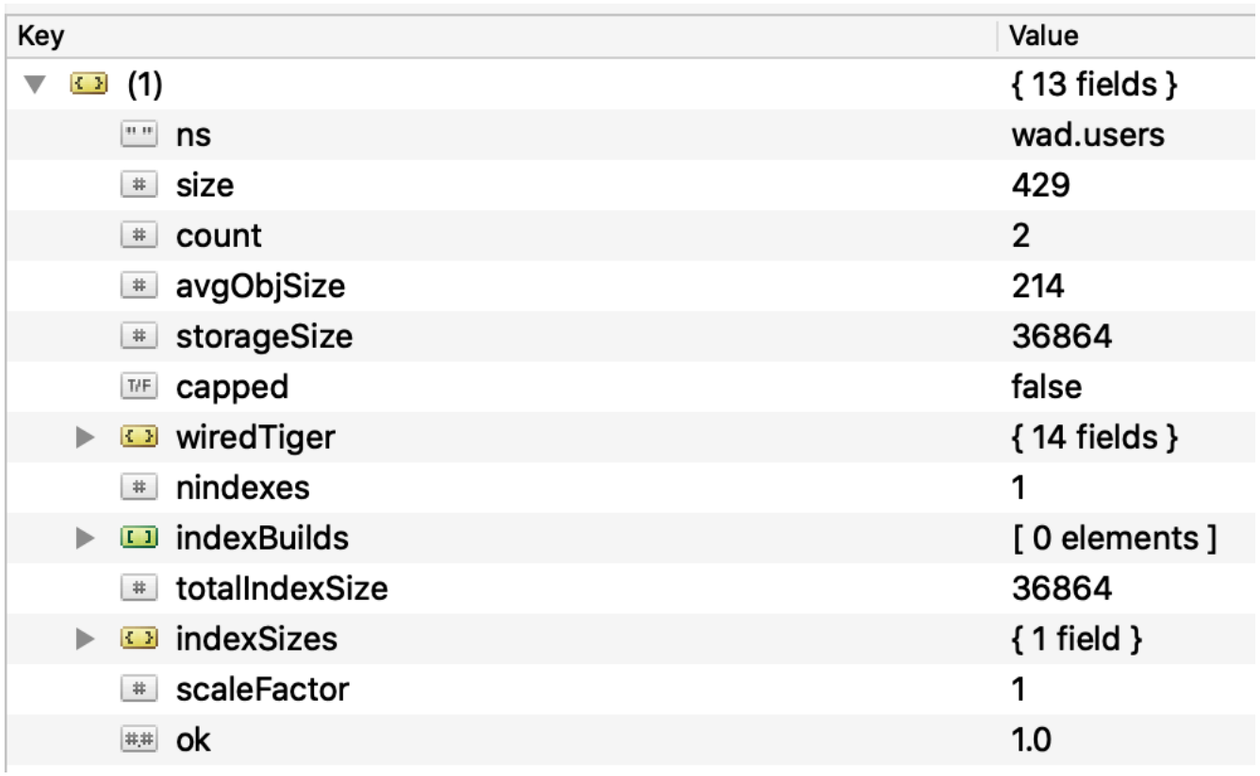
CLI Queries

List and use

```
> show dbs
admin   0.000GB
config  0.000GB
local   0.000GB
wad     0.000GB
> use wad
switched to db wad
> show collections
blogs
news
users
```

Iterate over collections

```
> db.getCollectionNames().forEach(function(collname) {
... print(collname + ": " + db[collname].count({}));
... })
blogs: 0
news: 0
users: 2
> db.users.stats()
{
    "ns" : "wad.users",
    "size" : 429,
    "count" : 2,
    "avgObjSize" : 214,
    "storageSize" : 36864,
    "capped" : false,
    ...
```



Key	Value
(1)	{ 13 fields }
ns	wad.users
size	429
count	2
avgObjSize	214
storageSize	36864
capped	false
wiredTiger	{ 14 fields }
nindexes	1
indexBuilds	[0 elements]
totalIndexSize	36864
indexSizes	{ 1 field }
scaleFactor	1
ok	1.0

Insert data

```
> db.users.insert({"username" : "admin",
"password" : "222", "registerDate" :
ISODate("2020-04-18T11:00:00Z")})
WriteResult({ "nInserted" : 1 })
```

```
> db.users.insert({"username" : "guest"})
WriteResult({ "nInserted" : 1 })
```

```
_id: ObjectId("5e998e4b124338fa2eacb9b9")
username: "admin"
password: "222"
registerDate: 2020-04-18T11:00:00.000+00:00
```

```
_id: ObjectId("5e998e73124338fa2eacb9ba")
username: "guest"
```

Insert data

```
> db.news.insert(
{"title": "WAD Lecture #4", "content":
"Content is empty for now", "createDate":
ISODate("2020-04-18T12:00:00Z"), "tags":
["education", "wad", "databases"]
})
WriteResult({ "nInserted" : 1 })
```

```
_id: ObjectId("5e9993eb124338fa2eacb9c5")
title: "WAD Lecture #4"
content: "Content is empty for now"
createDate: 2020-04-18T12:00:00.000+00:00
tags: Array
  0: "education"
  1: "wad"
  2: "databases"
```

ObjectId

- Default primary key
- Generates automatically
- 12 bytes size

Size	Description
4 bytes	Seconds since Unix epoch
3 bytes	Machine identifier
2 bytes	Process id
3 bytes	Counter starting from random value

ObjectId

```
> ObjectId()
ObjectId("5e999088124338fa2eacb9bb")
> ObjectId()
ObjectId("5e999089124338fa2eacb9bc")
> ObjectId()
ObjectId("5e999089124338fa2eacb9bd")
> ObjectId()
ObjectId("5e99908a124338fa2eacb9be")
> ObjectId()
ObjectId("5e99908a124338fa2eacb9bf")
> ObjectId()
ObjectId("5e99908b124338fa2eacb9c0")
> ObjectId()
ObjectId("5e99908b124338fa2eacb9c1")
> ObjectId()
ObjectId("5e99908c124338fa2eacb9c2")
```

>>> 0x5e999088
1587122312

Timestamp Converter

1587122312

Is equivalent to:

04/17/2020 @ 11:18am (UTC)

2020-04-17T11:18:32+00:00 in ISO 8601

Fri, 17 Apr 2020 11:18:32 +0000 in RFC 822, 1036, 1123, 2822

Friday, 17-Apr-20 11:18:32 UTC in RFC 2822

2020-04-17T11:18:32+00:00 in RFC 3339

Lookup data

```
> db.users.find()
{ "_id" : ObjectId("5e9975a7e8de390f5968e28d"), "username" :
"user", "password" : "123456", "registerDate" :
ISODate("2020-04-18T12:00:00Z") }
{ "_id" : ObjectId("5e9976a42482b3456c1dc4f6"), "firstName" :
"John", "lastName" : "Smith", "isAlive" : true, "age" :
NumberLong("27000000666660"), "AgE" : "123", "address" :
{ "streetAddress" : "21 2nd Street", "city" : "New York",
"state" : "NY", "postalCode" : "10021-3100" },
"phoneNumbers" : [ { "type" : "home", "number" : "212
555-1234" }, { "type" : "office", "number" : "646
555-4567" } ], "children" : [ ], "spouse" : null }
{ "_id" : ObjectId("5e998e4b124338fa2eacb9b9"), "username" :
"admin", "password" : "222", "registerDate" :
ISODate("2020-04-18T11:00:00Z") }
{ "_id" : ObjectId("5e998e73124338fa2eacb9ba"), "username" :
"guest" }
```

Lookup data

```
> db.users.find({"username": "user"})
{
"_id" : ObjectId("5e9975a7e8de390f5968e28d"),
"username" : "user",
"password" : "123456",
"registerDate" : ISODate("2020-04-18T12:00:00Z")
}
> db.news.find({"tags.0": "education"})
{ "_id" : ObjectId("5e9993eb124338fa2eacb9c5"),
"title" : "WAD Lecture #4", "content" : "Content
is empty for now", "createDate" :
ISODate("2020-04-18T12:00:00Z"), "tags" :
[ "education", "wad", "databases" ] }
```

Lookup data

```
> db.news.find({"createDate": {$gte: new
ISODate("2012-01-12T20:15:31Z")}})
{ "_id" : ObjectId("5e9993eb124338fa2eacb9c5"),
"title" : "WAD Lecture #4", "content" : "Content
is empty for now", "createDate" :
ISODate("2020-04-18T12:00:00Z"), "tags" :
[ "education", "wad", "databases" ] }

> db.news.find({"createDate": {$lt: new
ISODate("2012-01-12T20:15:31Z")}})
>
```

https://docs.mongodb.com/manual/tutorial/query-documents/

Remove

```
> db.users.remove({})
WriteResult({ "nRemoved" : 4 })
> db.news.remove({"tags.1": "wad"})
WriteResult({ "nRemoved" : 1 })
```

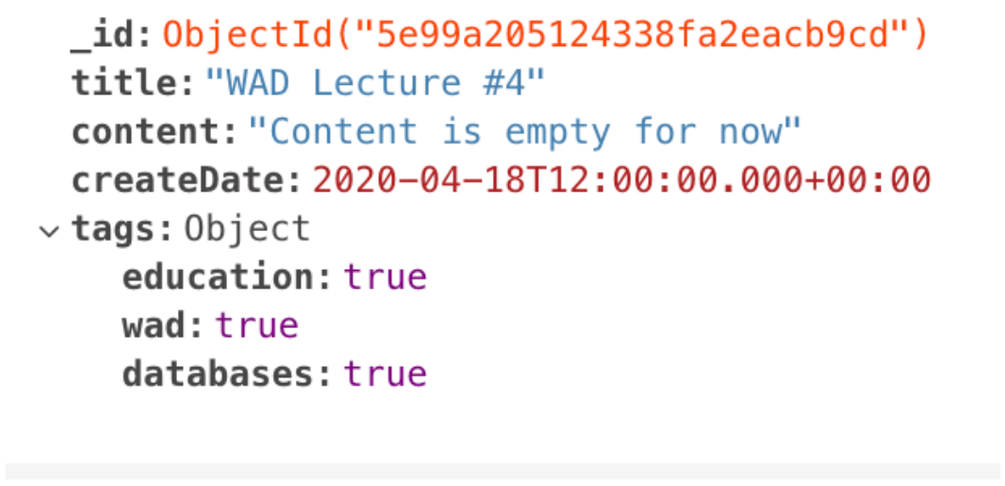
```
> db.news.insert({"title": "WAD Lecture #4",
"content": "Content is empty for now",
"createDate": ISODate("2020-04-18T12:00:00Z"),
"tags": {"education":true, "wad":true,
"databases":true}})
WriteResult({ "nInserted" : 1 })

> db.news.remove({"tags.wad": true})
WriteResult({ "nRemoved" : 1 })
```

Remove

```
> db.users.remove({})
WriteResult({ "nRemoved" : 4 })
> db.news.remove({"tags.1": "wad"})
WriteResult({ "nRemoved" : 1 })

> db.news.insert({"title": "WAD Lecture #4", "content":
"Content is empty for now", "createDate":
ISODate("2020-04-18T12:00:00Z"), "tags":
{"education":true, "wad":true, "databases":true}})
WriteResult({ "nInserted" : 1 })

> db.news.remove({"tags.wad": true})
WriteResult({ "nRemoved" : 1 })

> db.news.remove({"tags.wad": {$exists: true}})
WriteResult({ "nRemoved" : 1 })
```

Update

```
> db.news.updateMany( {"tags.wad": true},
{$set: {"tags.python":true}})
{ "acknowledged" : true, "matchedCount" : 2,
"modifiedCount" : 2 }
```



Upsert

▼ (1) ObjectId("5e99a2cb124338fa2eacb9cf")	{ 3 fields }
_id	ObjectId("5e99a2cb124338fa2eacb9cf")
username	user
password	user
▼ (2) ObjectId("5e99a2d1124338fa2eacb9d0")	{ 3 fields }
_id	ObjectId("5e99a2d1124338fa2eacb9d0")
username	admin
password	admin

```
> db.users.update({"username":"user"}, {$set: {"password":
"newpass"}}, {upsert: true})
WriteResult({ "nMatched" : 1, "nUpserted" : 0,
"nModified" : 1 })
> db.users.update({"username":"guest"}, {$set: {"password":
"newpass"}}, {upsert: true})
WriteResult({
    "nMatched" : 0,
    "nUpserted" : 1,
    "nModified" : 0,
    "_id" : ObjectId("5e99a4ae2482b3456c1dd2cc")
})
```

Limit, Skip

```
> db.users.find({}).limit(3)
5e99a2cb124338fa2eacb9cf
5e99a2d1124338fa2eacb9d0
5e99a4ae2482b3456c1dd2cc
```

```
> db.users.find({}).limit(1).skip(0)
{ "_id" : ObjectId("5e99a2cb124338fa2eacb9cf"),
"username" : "user", "password" : "newpass" }
> db.users.find({}).limit(1).skip(1)
... 5e99a2d1124338fa2eacb9d0...
> db.users.find({}).limit(1).skip(2)
5e99a4ae2482b3456c1dd2cc
```

Sort

```
> db.users.find({}).sort({"username":1})
admin, guest, user
```

```
> db.users.find({}).sort({"username":-1})
user, guest, admin
```

Two fields:

```
> db.users.find({}).sort({"age": -1,
"username": -1})
```

Import and Export

```
mongodump --host "localhost" --port 27017 -d
wad -o ./output
```

```
mongorestore --host "localhost" --port 27017
-d wad ./output
```

Literature

- MongoDB Basics: https://university.mongodb.com/courses/M001/about

- Dump & restore: https://docs.mongodb.com/manual/tutorial/backup-and-restore-tools/

- ObjectId: https://mongodb.github.io/node-mongodb-native/2.0/tutorials/objectid/

Demo

Python & MongoDB

Basic usage

```
from pymongo import MongoClient
client = MongoClient('localhost', 27017)
db = client.wad
```

Insert data

```
username = random.randint(0, 10)
password = random.randint(0, 100)
db.users.insert({
    "username": username,
    "password": password
})
```

```
db.users.insert_many(users)
```

```
db.users.find_one({"username": "user"})
```

```
db.users.find_one({"username": "user", "password":
                                        "pass"})
```

```
for user in db.users.find({"username": 3}):
    print(user)
```

Flask-PyMongo

```
from flask import Flask, render_template, request, redirect
from flask_pymongo import PyMongo

app = Flask(name)
app.config["MONGO_URI"] = "mongodb://localhost:27017/wad"
mongo = PyMongo(app)


@app.route("/")
def home_page():
    online_users = mongo.db.users.find({})
    return render_template("list.html", users=online_users)


if name == "main":
    app.run(host='localhost', port=5000, debug=True)
```

Faker

```
from faker import Faker
faker = Faker()
```

faker.name()

faker.address()

faker.text()

Use `faker.Faker()` to create and initialize a faker generator, which can generate data by accessing properties named after the type of data you want.

```
from faker import Faker
fake = Faker()

fake.name()
# 'Lucy Cechtelar'

fake.address()
# '426 Jordy Lodge
#  Cartwrightshire, SC 88120-6700'

fake.text()
# 'Sint velit eveniet. Rerum atque repellat voluptatem quia rerum. Numquam excepturi
#  beatae sint laudantium consequatur. Magni occaecati itaque sint et sit tempore. Nesciunt
#  amet quidem. Iusto deleniti cum autem ad quia aperiam.
#  A consectetur quos aliquam. In iste aliquid et aut similique suscipit. Consequatur qui
#  quaerat iste minus hic expedita. Consequuntur error magni et laboriosam. Aut aspernatur
#  voluptatem sit aliquam. Dolores voluptatum est.
#  Aut molestias et maxime. Fugit autem facilis quos vero. Eius quibusdam possimus est.
#  Ea quaerat et quisquam. Deleniti sunt quam. Adipisci consequatur id in occaecati.
#  Et sint et. Ut ducimus quod nemo ab voluptatum.'
```

Literature

- Pymongo docs: https://api.mongodb.com/python/3.8.0/
- Flask-PyMongo: https://flask-pymongo.readthedocs.io/en/latest/
- Python faker: https://faker.readthedocs.io/en/master/

Demo

Indexes

```python
from pymongo import MongoClient
import random
client = MongoClient('localhost', 27017)
db = client.wad

def generate_users():
    for user in range(1000):
        db.users.insert_many([{
            "username": random.randint(0, 1000000),
            "password": random.randint(0, 1000000)
    } for i in range(5000)])
```

5100000 documents in collection

With index

```
db.getCollection('users').createIndex({"username": 1})
```

```
db.getCollection('users').find({"username":811091})
```

users 0.05 sec.

Key	Value
(1) ObjectId("5e9a96e8472c0fe78d54d383")	{ 3 fields }
(2) ObjectId("5e9a9740487276165df70a88")	{ 3 fields }
(3) ObjectId("5e9a9755487276165d057e52")	{ 3 fields }
(4) ObjectId("5e9a975c487276165d0adc73")	{ 3 fields }
(5) ObjectId("5e9a9764487276165d107458")	{ 3 fields }
(6) ObjectId("5e9a9791487276165d30ff36")	{ 3 fields }
(7) ObjectId("5e9a9796487276165d34fa35")	{ 3 fields }
(8) ObjectId("5e9a979e487276165d3afd63")	{ 3 fields }

Without index

```
db.getCollection('users').find({"username":811091})
```

users 5.24 sec.

Key	Value
(1) ObjectId("5e9a96e8472c0fe78d54d383")	{ 3 fields }
(2) ObjectId("5e9a9740487276165df70a88")	{ 3 fields }
(3) ObjectId("5e9a9755487276165d057e52")	{ 3 fields }
(4) ObjectId("5e9a975c487276165d0adc73")	{ 3 fields }
(5) ObjectId("5e9a9764487276165d107458")	{ 3 fields }
(6) ObjectId("5e9a9791487276165d30ff36")	{ 3 fields }
(7) ObjectId("5e9a9796487276165d34fa35")	{ 3 fields }
(8) ObjectId("5e9a979e487276165d3afd63")	{ 3 fields }

Explain

db.getCollection('users').find({"username":811091}).explain("executionStats")

```
"executionStats" : {
    "executionSuccess" : true,
    "nReturned" : 8,
    "executionTimeMillis" : 3136,
    "totalKeysExamined" : 0,
    "totalDocsExamined" : 5100003,
    "executionStages" : {
        "stage" : "COLLSCAN",
        "filter" : {
```

~5s

db.getCollection('users').find({"username":811091}).limit(1).explain("executionStats")

~0.08s

```
"executionStats" : {
    "executionSuccess" : true,
    "nReturned" : 1,
    "executionTimeMillis" : 52,
    "totalKeysExamined" : 0,
    "totalDocsExamined" : 50016,
    "executionStages" : {
        "stage" : "LIMIT",
```

Explain with index

db.getCollection('users').find({"username":811091}).explain("executionStats")


```
"executionStats" : {
    "executionSuccess" : true,
    "nReturned" : 8,
    "executionTimeMillis" : 0,
    "totalKeysExamined" : 8,
    "totalDocsExamined" : 8,
    "executionStages" : {
```


~0.002s

db.getCollection('users').find({"username":811091}).limit(1).explain("executionStats")

~0.002s


```
"executionStats" : {
    "executionSuccess" : true,
    "nReturned" : 1,
    "executionTimeMillis" : 0,
    "totalKeysExamined" : 1,
    "totalDocsExamined" : 1,
    "executionStages" : {
        "stage" : "LIMIT",
```

Text search

⚙️ **Generate**

```
db.stores.insert_many(
    [
      { "name": "Java Hut", "description": "Coffee and cakes" },
      { "name": "Burger Buns", "description": "Gourmet hamburgers" },
      { "name": "Coffee Shop", "description": "Just coffee" },
      { "name": "Clothes Clothes Clothes", "description": "Discount clothing" },
      { "name": "Java Shopping", "description": "Indonesian goods" }
    ]
)
db.stores.create_index([("name", "text"), ("description", "text")])
```

🔎 **Query**

```
db.stores.find( { $text: { $search: "java coffee shop" } } )
```

```
db.getCollection('stores').find({ $text: { $search: "java coffee shop" } })
```

stores 0.003 sec.

Key	Value
(1) ObjectId("5e9a997a0c3169fb1ba1f726")	{ 3 fields }
_id	ObjectId("5e9a997a0c3169fb1ba1f726")
name	Coffee Shop
description	Just coffee
(2) ObjectId("5e9a997a0c3169fb1ba1f724")	{ 3 fields }
_id	ObjectId("5e9a997a0c3169fb1ba1f724")
name	Java Hut
description	Coffee and cakes
(3) ObjectId("5e9a997a0c3169fb1ba1f728")	{ 3 fields }
_id	ObjectId("5e9a997a0c3169fb1ba1f728")
name	Java Shopping
description	Indonesian goods

🔎 **Query** `db.stores.find( { $text: { $search: "\"coffee shop\"" } } )`

```
db.getCollection('stores').find({ $text: { $search: "\"coffee shop\"" } })
```

stores 0.003 sec.

Key	Value
(1) ObjectId("5e9a997a0c3169fb1ba1f726")	{ 3 fields }
_id	ObjectId("5e9a997a0c3169fb1ba1f726")
name	Coffee Shop
description	Just coffee

🔎 **Query**

```
db.stores.find( { $text: { $search: "java shop -coffee" } } )
```

```
db.getCollection('stores').find({ $text: { $search: "java shop -coffee" } })
```

stores 0.004 sec.

Key	Value
(1) ObjectId("5e9a997a0c3169fb1ba1f728")	{ 3 fields }
_id	ObjectId("5e9a997a0c3169fb1ba1f728")
name	Java Shopping
description	Indonesian goods

Literature

- Create index: https://docs.mongodb.com/manual/indexes/#create-an-index

- Text search: https://docs.mongodb.com/manual/text-search/

Demo

Assignment #4

Homework

Task #4 - Database

Reading → Coding → Deploy → Code-review

Reading

1. MongoDB get started: https://docs.mongodb.com/manual/tutorial/getting-started/
2. Pymongo: https://api.mongodb.com/python/current/tutorial.html
3. Flask pymongo: https://flask-pymongo.readthedocs.io/en/latest/

Coding

Preparations

1. Install Python programming language **v3.8.2**: https://www.python.org/downloads/
2. Install Flask framework with **pip**: https://docs.python.org/3/installing/index.html#basic-usage
3. Install PyMongo and Flask PyMongo with **pip**
4. Install MongoDB: https://docs.mongodb.com/manual/installation/

Basic part

1. Create web application, which can authenticate user with password:
    - Listen on `localhost:5000`
    - Render authentication form on `http://localhost:5000/`
    - Return static images and files on `http://localhost:5000/static/<image_name>`
    - Has secret page for authenticated users on `http://localhost:5000/cabinet`
2. Valid usernames and passwords should be stored in MongoDB database
3. You are allowed to use any JS or CSS frameworks
4. You are allowed to use only Python programming language and Flask framework
5. You are allowed to use only MongoDB as database

Optimal part

1. Add registration function to append new users on `http://localhost:5000/register/`
2. You can keep usernames/passwords only in MongoDB

Challenging part

(Part for those, who already knows all that stuff)

1. Implement `password change` feature
2. Fill database with 1 thousand, 1 million, 10 million, ... users with the help of Faker library
3. Add **index** to username and measure how response time is changed depending on the number of users. Results of the research append to the README.md file
4. You can draw a graph

Deploy

1. Register on GitHub: https://github.com/
2. Join our organization: https://github.com/itmo-wad/
3. You can create new personal repository or use repository for the previous tasks (but don't remove old files, just append new directories)
4. Commit and push your sources to GitHub. And don't forget to describe shortly what have you done in `README.md` file. Use Markdown format: https://guides.github.com/features/mastering-markdown/
5. Also save data from MongoDB as dump or as simple JSON file in the repository

Code-review

1. Communicate in Telegram chat
2. Help others to complete the assignment

Teams

Team 1	Time picker	https://github.com/itmo-wad/time-picker
Team 2	📆🙋‍♂️ Who when can	https://github.com/itmo-wad/Who_when_can
Team 3	🔄🍕 Ur-opinion	https://github.com/itmo-wad/Ur-opinion
Team 4	CatchMe	
Team 5		
Team 6	🇨🇭🔪 Swiss knife	
Team 7	😄⛏️ Emoji picker	https://github.com/itmo-wad/emoji_picker

Practice time