Introducton to Data Engineering 9

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‘The cost of managing traditional databases is high. Mistakes made during routine maintenance are responsible for 80 percent of application downtime.’

Dev Ittycheria, President and CEO of MongoDB

1. Recall
2. NoSQL
3. MongoDB: Document based NoSQL
4. ElasticSearch: A different kind of Document-based NoSQL DB

The main aspects of Relational Databases:

- Very structured
  - **Tables**
  - **Typed attributes**
  - Integrity **constraints** and **relations**
    - ⋆ Uniqueness of **primary keys** (integrity)
    - ⋆ Existence of **foreign keys** (relations)
    - ⋆ Etc.
- Can be **formalized with diagrams**
  - UML, MERISE, etc
- Use **SQL** language for DB operations

idetudiant	nom	prenom	ville
1	Perrier	Jean	Rennes
2	Martin	Aline	Mulhouse

Figure: SQL example: "SELECT nom,prenom FROM etudiant;

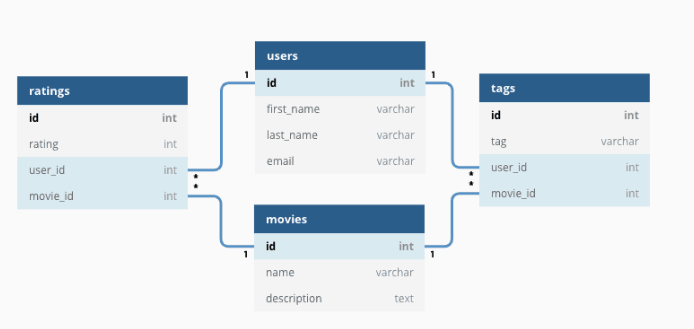


Figure: Example of a relational database diagram

- There are four tables
- Each table has a set of typed fields
- Tables have relations

Relation Databases have pros, and cons...

- Relation Databases are **difficult to distribute on several servers**
- They face a **scaling problem**
  - A bigger database = a more powerful server = limitations
- They have a **rigid definition** (schema):
  - Changing the schema is hard (require "migrations" = dangerous)
- They are **slow** (because of all the relations to consider)

A complex Relational Database is hard to maintain...

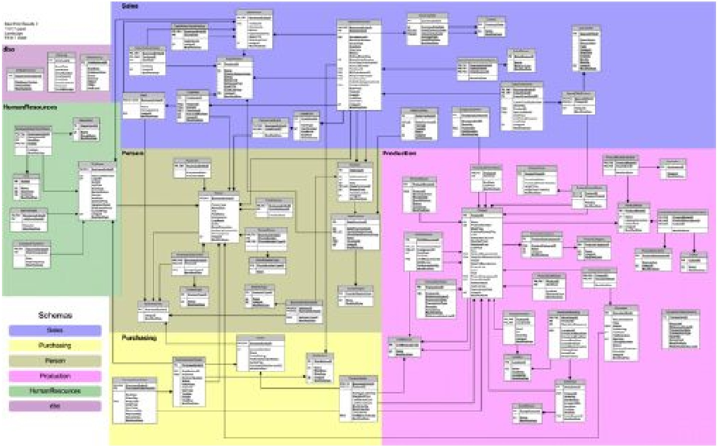


Figure: Example of a complex Relational Database

All these cons make it extremely difficult to deal with Big Data's three Vs...

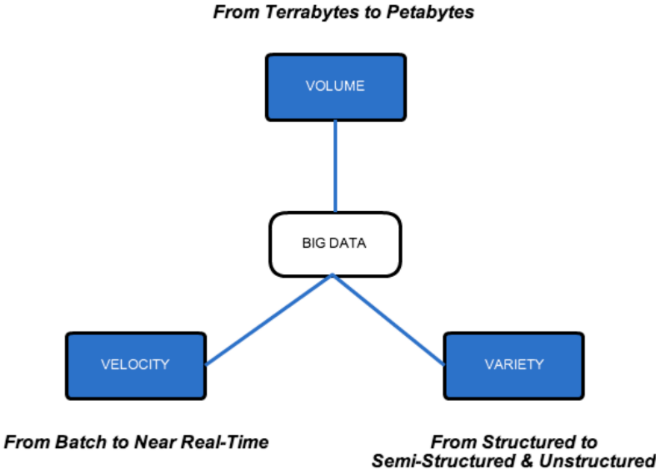


Figure: The three Vs.

Biggest issue of Relational DB with Big Data is: **scaling**

Why?

Relational DB **cannot easily distribute the storage capacity on other nodes because of the complex relations and constraints** existing between the tables of a relational database

Indeed, we can only add storage capacity on the same server and also add more processing power (vertical scaling):

Figure: Vertical scaling of a server containing a Relational DB

In the previous course, we saw that **the way to deal with Big Data is horizontal scaling** (adding nodes in a cluster):

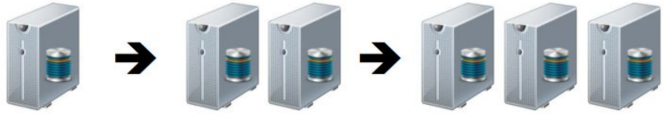
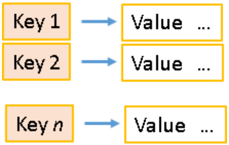


Figure: Horizontal scaling of a cluster: adding more nodes to increase capacity

- Storing data on a cluster of servers and **benefit from horizontal scaling is possible using NoSQL databases**
- NoSQL means « Not-Only SQL » and not No SQL (NOTE: some NoSQL databases partially understand SQL)
- **NoSQL databases are schemeless**
- Data can be stored with different scheme on the fly, **there are no fixed schemes**
- **Removing the constraints of Relational DB permits to distribute the DB** on multiples server nodes

In a NoSQL database, the information is **stored as key and value pairs**:



Example:

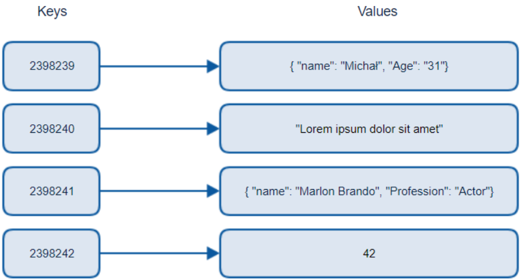


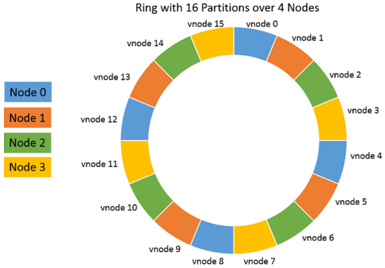
Figure: Contrary to Relational DB, all the information is stored in the "values field" and can be various (JSON, strings, numbers, etc)

A NoSQL database **can be easily distributed on different nodes of a cluster using of a hash function**:

It is easy to know in which node (or server) is located the data by computing the result of a hash function:

A hash function is a function **taking the key in input and giving a number in output which is the node id of the cluster**:

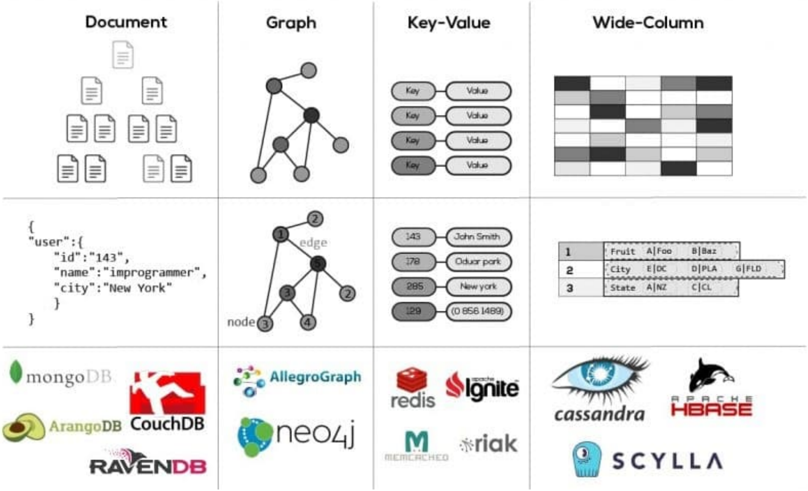
Example: HASH(key) $\rightarrow$ [1 15]



- Example: we want the values of key 2398239, HASH(2398239)=12. So the values are in the virtual node 12 (a partition of Node 0)
- Here we have 16 virtual nodes, HASH can be just the modulo of 16 (HASH(X)=X mod 16)
- If we want to add a new nodes to our cluster: we just have to change the hash function (HASH(X) = X mod 20)
- Adding nodes to a NoSQL cluster is very easy... It scales horizontally easily.

Different types of NoSQL databases, for example:

- **Document DB**: MongoDB, CouchDB, ElasticSearch, etc.
- **Column DB**: Cassandra, etc.
- **Key-value purely based**: Redis, etc.
- **Cache system**: Redis, etc.
- **Graph**: Neo4j, etc.


Document
Graph
Key-Value
Wide-Column
Key
Value
{
"user":{
"id":"143",
"name":"improgrammer",
"city":"New York"
}
}
edge
node
143
John Smith
178
Oduor park
285
New york
129
(0 856 1489)
1
2
3
Fruit A|Foo B|Baz
City E|DC D|PLA G|FLD
State A|NZ C|CL
mongoDB
CouchDB
ArangoDB
RAVENDB
AllegroGraph
neo4j
redis
Ignite
MEMCACHED
riak
cassandra
APACHE HBASE
SCYLLA

There are many NoSQL databases but **no NoSQL standard**

Common points between NoSQL DBs:

- They have an **implicit schema**:
  - Data **schema not predefined on the server side**
  - The **client application structures the data**
  - Some exceptions: Cassandra V2
- There are **no relations**:
  - No relationship between data or between elements of two collections
  - Some exceptions: Neoj4 and Hive in some cases

In this course

We will see **MongoDB** and **ElasticSearch**

Advantages and disadvantages of NoSQL and Relational Databases.

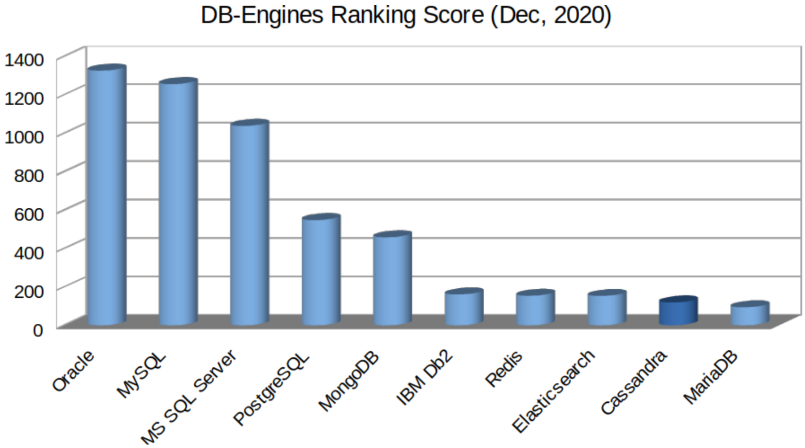
NoSQL:

- **Advantages**:
  - Can **deal with large volumes of structured, semi-structured, and unstructured data**
  - Set of **functions or API easier to use than SQL**
  - **Efficient horizontal scaling** (instead of expensive vertical scaling)
- **Disadvantages**:
  - **Less support** since NoSQL databases are usually open-source
  - NoSQL databases **require technical skill** in order to install and maintain
  - **Less mature**: they are still growing and many features have to be implemented

Relational databases:

- **Advantages**:
  - Can **handle very complex queries, database transactions, and routine analysis of data**
  - Respect "ACID" (**Atomity**, **Consistency**, **Isolation**, **Durability**): properties ensuring reliable database transactions
  - Can **handle constraints** (Ex: make sure data can only be deleted if some conditions are met)
- **Disadvantages**:
  - Cannot store **too complex or too large** images, numbers, designs and multimedia products
  - Can **become very costly in maintenance and fragile**

MongoDB: A **document-based NoSQL database** and the **most popular NoSQL database**.



- Documents are stored using a **hierarchical representation**
  - Documents are written with the **BSON** syntax
    - **BSON = Binary JSON**
    - BSON: **extension of the JSON format** containing additional types
- The DB is **schemaless**
  - **No mandatory attribute**
  - **No fixed type** for an attribute
  - **No need to perform complex and dangerous DB migrations**
- MongoDB documents are **similar Python dictionaries**
  - Set of key/value pairs.

Note

Because NoSQL DBs are schemaless, constraints and data relations must be explicitly handled on the application-side.

Example of a BSON MongoDB document:

```
{ ‘name’ :’Jean’, ‘height’:170}
{ ‘name’ : ‘Jacques’, ‘height’ : 180, ‘job’ :’teacher’}
{ ‘type’ : ‘car’, ‘brand’ : ‘renault’, ‘price’ : 1500 }
{ ‘type : ‘house’}
```

Properties of MongoDB documents:

- Keys...
  - are **string** of characters
  - are **case sensitives**
  - must **be unique**:
    - {"name": "Romain", "height":185, "name": "Tavenard"} **not** valid
- Values...
  - are **case sensitives**: {"name": "Roman"} != {"name": "roman"}
  - are **type sensitives**: {"height": "185"} != {"height": 185}

MongoDB documents are stored in collections
(a **collection = set of documents**)

- **Collection**:
  - Example: [{"name": "Romain", "height": 185}, {"name": "Paul", "height": "172"}, {"name": "Romain", "height": 163, "weight_kg": 65}]
  - No schema: keys, values and types can change from one doc to another

Comparison of naming with Relational Databases:

Relational DB	**Document-based DB**
Table	Collection
Recording	Document

Focus on the **JSON format**:

- Recall: JSON means **JavaScript Object Notation**
- Example of a JSON document: {"name": "Romain", "height": 185}
- Data types:
  - null: {"x": null}
  - Boolean: {"x": true}
  - Number: {"x": 3.14}
  - String: {"x": "abcdef"}
  - Array: {"x": [1, 5, 7]}
  - Date: {"x": new Date()}

How to interogate the DB?

- **No need of SQL**
- Can read/write the DB using **JavaScript** or **Python**
- Languages allowing more than data access
  - Definition of variables
  - Loops
  - Etc.

How to use MongoDB on Linux:

Launch the MongoDB deamon (depend on your system). On GNU/Linux systems using "systemd":

```
$ systemctl start mongodb.service
```

Launch mongo:

```
$ mongo
```

Create a database (or use it, if it already exist):

```
> use my_db
```

Create a collection:

```
> db.createCollection("my_collection")
```

Display the databases:

```
> show dbs
```

Display the collections:

```
> show collections
```

We can interrogate MongoDB with Python using the "pymongo" module:

Let's connect to the MongoDB and fetch the database « my_db » we just created:

```
$ python
> from pymongo import MongoClient
> client = MongoClient()
> col = client.my_db
```

Let's see how to perform the basic **CRUD** operations using pymongo (**CRUD = Create Remove Update Delete**)

Create:

Insert a single document using **insert_one(document)**:

```
> result = col.insert_one({'x':1})
> result.inserted_id
ObjectId('583c16b9dc32d44b6e93cd9b')
```

Insert multiple documents using **insert_many(documents)**:

```
> result = col.insert_many([{'x': 2}, {'x': 3}])
> result.inserted_ids
[ObjectId('583c17e7dc32d44b6e93cd9c'),
ObjectId('583c17e7dc32d44b6e93cd9d')]
```

Update:

Update a single document matching a filter using **update_one(filter, update, upsert=False)**:

```
> result = col.update_one({'x': 1}, {'x': 3})
```

Update one or more documents matching a filter using **update_many(filter, update, upsert=False)**:

```
> result = col.update_many({'x': 1}, {'x': 3})
```

Read:

Query the database using **find(filter=None, projection=None, skip=0, limit=0, no_cursor_timeout=False)**:

The filter argument is a prototype document that all results must match:

```
> result = col.find({'x': 1})
```

Get a single document from the collection using **find_one(filter=None)**:

```
> result = col.find_one()
```

Delete:

Delete a single document matching a filter using **delete_one(filter)**:

```
> result = col.delete_one({'x': 1})
> result.deleted_count
```

Delete one or more documents matching a filter using **delete_many(filter)**:

```
> result = col.delete_many({'x': 1})
> result.deleted_count
```

pymongo also provides **find_one_and_delete()** and **find_one_and_replace()** functionality.

More information

For more information see the official documentation: https://pymongo.readthedocs.io/en/stable/tutorial.html

1. Recall
2. NoSQL
3. MongoDB: Document based NoSQL
4. ElasticSearch: A different kind of Document-based NoSQL DB

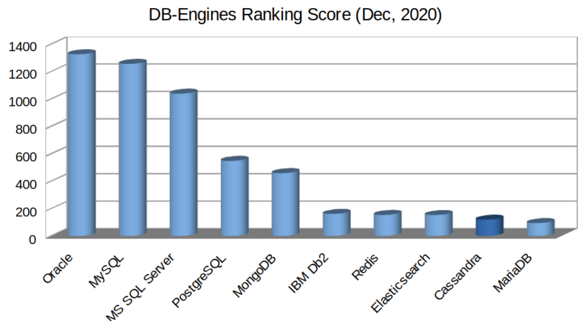
ElasticSearch...

- is a different kind of document-based NoSQL database
- is a also powerful **real-time distributed search and analysis tool**

ElasticSearch is used for:

- Full text search
- Structured search
- Analysis
- All three combined...

ElasticSearch is also a very popular NoSQL DB:



It is used by:

- Wikipedia (http://fr.wikipedia.org)
- The Guardian (http://www.theguardian.com)
- StackOverflow (http://stackoverflow.com/)
- GitHub (https://github.com/)
- Goldman Sachs (http://www.goldmansachs.com/)

ElasticSearch is...

- A distributed **real-time** document DB where **all fields are undefined and searchable**
- A distributed **search engine with real-time analysis**
- Capable of supporting a scalability of **hundreds of servers and petabytes of structured or unstructured data**
- Allow to:
  - Perform and combine **various searches** on structured, unstructured, geolocation or indicator data
  - **Explore trends and identify patterns** in the data

Why Elasticsearch?

Most databases are inadequate at extracting actionable data. They **cannot do full-text search, handle synonyms, and sort documents by relevance**. Besides, they **do not do it in real-time**.

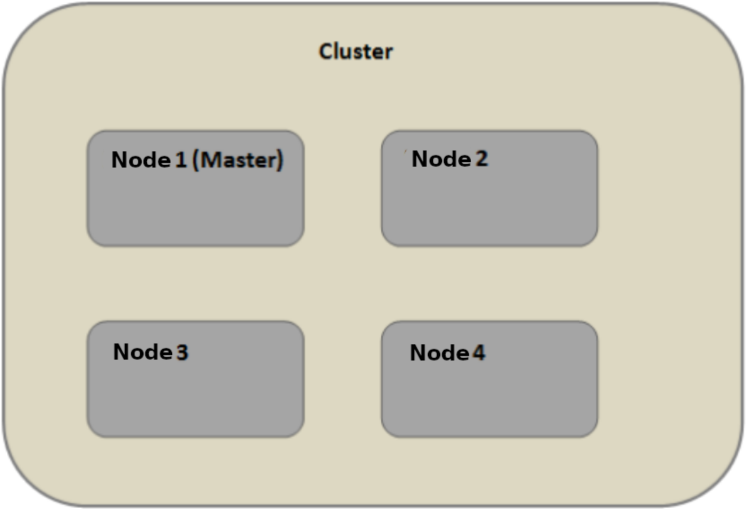
How are stored the documents?

- The **content of each document is indexed**
- A document **has a Type** (which defines its mapping)
- **Types** are contained in an **Index**

Comparison ElasticSearch VS Relational Databases VS MongoDB:

Relational DB	Database	Tables	Rows	Columns
MongoDB	Database	Collections	Documents	Fields
Elasticsearch	Index	Types	Documents	Fields

Alike MongoDB, **documents are stored in a cluster**. And we can horizontally scale the cluster by adding nodes:

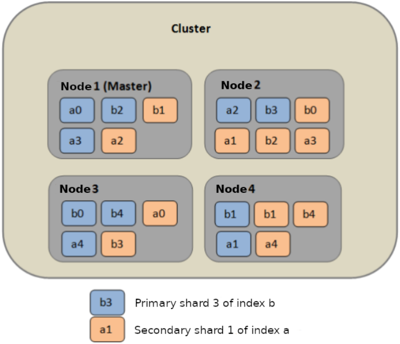


ElasticSearch is not really a DataBase, **it is an index**.

- An index is a **logical storage space for documents of the same type** split into one or more Primary Shards
- An index can be **replicated on zero or more Secondary Shards**

Shards

- **Primary Shards**: This is a partition of the index (Default: 5 Primary Shards)
- **Secondary Shards**: Copies of the Primary Shards (Zero to several times number of Primary Shards)



Why we have shards?

- It's **faster to write and read** big amount of data
- It is possible to write on different nodes in the same time, and collect from different locations: **no funnel effect**
- **Shards are replicated** to make the cluster more robust

ElasticSearch Document

- 1 document = **a simple record in an ElasticSearch shard**
- Documents are structured as JSON object and must belong to a **Type** (defining its structure)

Example:

```
{
    "nom": "Paris",
    "codePostal":"75000",
    "monuments": [
        {
            "nom": "Arc de Triomphe"
        },
        {
            "nom": "Tour Eiffel"
        }
    ]
}
```

ElasticSearch offers a **REST API** to perform operations through HTTP (**GET, PUT, POST and DELETE methods** can be performed)

API calls are **performed on an URL address with the following syntax**: http://localhost:9200/[index]/[type]/[id]/[action]

- index: Name of the index
- type: Name of the document type
- id: ID of the document
- action: Action to perform

Note

To call the API through HTTP we can use the "curl" command (or Python+requests)

Let's see how create an Index named "articles":

```
curl -X PUT "localhost:9200/articles?pretty" -H 'Content-Type: application/json' -d'
{
    "settings" : {
        "index" : {
            "number_of_shards" : 3,
            "number_of_replicas" : 2
        }
    }
}
```

And a type:

```
curl -XPUT "http://localhost:9200/articles/_doc/_mapping" -d
{
   "_doc": {
      "properties": {
         "title": {
            "type": "string"
         },
         "description": {
            "type": "string"
         },
     "author": {
            "type": "string"
         }
      }
    }
}
```

Let's see how to index a document (= insert a document):

```
curl -XPOST 'localhost:9200/articles/_doc/1?pretty' -d '{"title": "python tuples",
"description": "practical operations with python tuples","author": "santosh"}'
-H 'Content-Type: application/json'
```

```
This will return :

% Total    % Received % Xferd  Average Speed   Time    Time     Time  Current Dload  Upload   Total   Spent
100   377  100   222  100   155    222    155  0:00:01 --:--:--  0:00:01  1008{
"_index" : "articles",
"_type" : "_doc",
"_id" : "1",
"_version" : 1,
"result" : "created",
"_shards" : {
"total" : 2,
"successful" : 2,
"failed" : 0
},
"_seq_no" : 0,
"_primary_term" : 1
}

If it succed it will return a HTTP 200 code.
```

Let's see how to delete a document:

```
curl -XDELETE 'localhost:9200/articles/_doc/1?pretty'
% Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
Dload  Upload   Total   Spent    Left  Speed
100   241  100   241    0     0    241      0  0:00:01 --:--:--  0:00:01  1928{
"_index" : "articles",
"_type" : "_doc",
"_id" : "1",
"_version" : 2,
"result" : "deleted",
"_shards" : {
"total" : 2,
"successful" : 2,
"failed" : 0
},
"_seq_no" : 1,
"_primary_term" : 1
}
```

And finally an example of a search:

```
curl -XPOST "https://localhost:9200/_search" -d'{ "query": { "query_string": { "query": "hello" } } }'
Results:
{
  "took": 12,
  "timed_out": false,
  "_shards": {
     "total": 12,
     "successful": 12,
     "failed": 0
  },
  "hits": {
     "total": 1,
     "max_score": 0.19178301,
     "hits": [
       {
            "_index": "my-first-index",
            "_type": "message",
            "_id": "AUqiBnvdK4Rpq0ZV4-Wp",
            "_score": 0.19178301,
            "_source": {
                "text": "Hello world!"
                }
            }
       ]
     }
  }
```

Official doc

More information about the Elasticsearch REST API on this website: https://www.elastic.co/guide/en/elasticsearch/reference/current/docs.html

As mentioned above, it's possible to use **ElasticSearch with Python**:

```
settings = {
    "settings": {
        "number_of_shards": 3,
        "number_of_replicas": 2
    },
    "mappings": {
        "profile": {
            "properties": {
                "name": {
                    "type": "string"
                },
          "age": {
                    "type": "integer"
                },
        "address": {
                    "type": "string"
                }
            }
        }
     }
}
from elasticsearch import Elasticsearch
# Connect to the elastic cluster
es=Elasticsearch([{'host':'localhost','port':9200}])
es.indices.create(index='people', body=settings)
```

```
document = {
    'name': 'Jean',
    'age': 19,
    'address': ‘Paris',
}
res = es.index(index="people", id=1, body=document)
print(res['result'])

res = es.get(index="people", id=1)
print(res['_source'])

es.indices.refresh(index="people")

res = es.search(index="people", body={"query": {"query_string": {"query" : "Jean"}}})

print("Got %d Hits:" % res['hits']['total']['value'])
for hit in res['hits']['hits']:
    print("%(timestamp)s %(author)s: %(text)s" % hit["_source"])
```

Official doc

More information about the Python Elasticsearch API here:
https://elasticsearch-py.readthedocs.io/en/6.8.2/api.html