DS-3002: Data Systems

An Overview of NoSQL Databases

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UNIVERSITY of VIRGINIA

NoSQL Databases

Understanding the Principles Behind NoSQL Databases

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But Then… An Explosion of Data – “BIG Data”

A Rapid, Exponential Proliferation of New Devices: The Internet of Things (IoT)

olume (Size)

- Explosion in social media, mobile apps, digital sensors, RFID, GPS, and more have caused exponential data growth.

elocity (Speed)

- Sources like social networking and sensor signals create data at a tremendous rate; making it a challenge to capture, store, and analyze that data in a timely or economical manner.

ariety (Structure)

- Traditionally BI has sourced structured data, but now insight must be extracted from unstructured or poly-schematic data like large text blobs, digital media, sensor data, etc.

eracity (Quality)

- The anonymity of the WWW, incredible sources like social networking and duplicate systems bring into question the authenticity of the information being generated and collected.

NoSQL: Not Only SQL

Key-value stores

- The simplest NoSQL database; based on “dictionaries” or “maps”.
- Items are stored in associative arrays; pairing a name (or "key"), with a value.
- **Riak, FoundationDB, and Redis**

Column stores

- Combines a key, value and timestamp for each item.
- Optimized for large datasets by storing columns of data together, rather than in rows.
- **Cassandra, BigTable and HBase**

Document databases

- Pairs keys with complex data structures (documents) using XML, JSON or BSON.
- Documents may contain key-value pairs, key-array pairs, and nested documents.
- **MongoDB, MarkLogic, and Apache CouchDB**

Graph stores

- Stores interrelated networks of data such as social connections, or network topologies.
- Optimized for interconnected data elements with an undetermined number of relations.
- **AllegroGraph, Neo4J and HyperGraphDB**.

NoSQL Databases

- NoSQL databases are defined by a collection of characteristics that they share rather than having a formal definition:

  Non-relational

  Scale-out

  Schema-less

- They were all born out of this desire to address new needs of the internet world.

Key–value databases	Column family databases
Document databases	Graph databases

JSON in NoSQL

How JSON sparked NoSQL

- Features of JSON:
  - *Data structure of the **web**.*
  - **Simple** data format.
  - Displaced more complex formats such as XML and *ML.
  - **Developer Friendly** (Supported in virtually every programming language)
  - **Agility** of JSON records.
  - **Lack of predefined schema** makes upgrades easy.


```
"firstName": "John",
"lastName": "Smith",
"age": 25,
"address": {
    "streetAddress": "21 2nd S
    "city": "New York",
    "state": "NY",
    "postalCode": 10021
},
"phoneNumbers": [
    {
        "type": "home",
```

RDBMS vs NoSQL

RDBMS

NoSQL

Consistency...?

Emphasis on **ACID** (Atomicity, Consistency, Isolation and Durability) Properties

Relational **SQL** databases are very **strongly consistent** ("C" in ACID)

Emphasis on Brewers **CAP** (Consistency, Availability and Partitions tolerance) theorem.

In **NoSQL** the **consistency varies** depending on the type of DB. For example

- In GraphDB such as Neo4J, consistency ensures that a relationship must have a start and end node
- In MongoDB, it automatically creates a unique rowid, using a 24bit length value

What are Relational DBs, NoSQL DBs good at?

Relational databases are good at **structured data** and **transactional, high-performance workloads.**

Offerings are proven and mature with a wide variety of tools available

NoSQL databases are good for non-relational data. **Schema-less architecture** allows for frequent changes to the database and easy addition of varied data to the system.
Allows for *heterogeneous* items (maybe not all blog posts have associated photos or video, etc…) This difference is okay! Very flexible!

Easily scalable (*horizontally*), runs well on distributed systems (***#CloudFirst***)

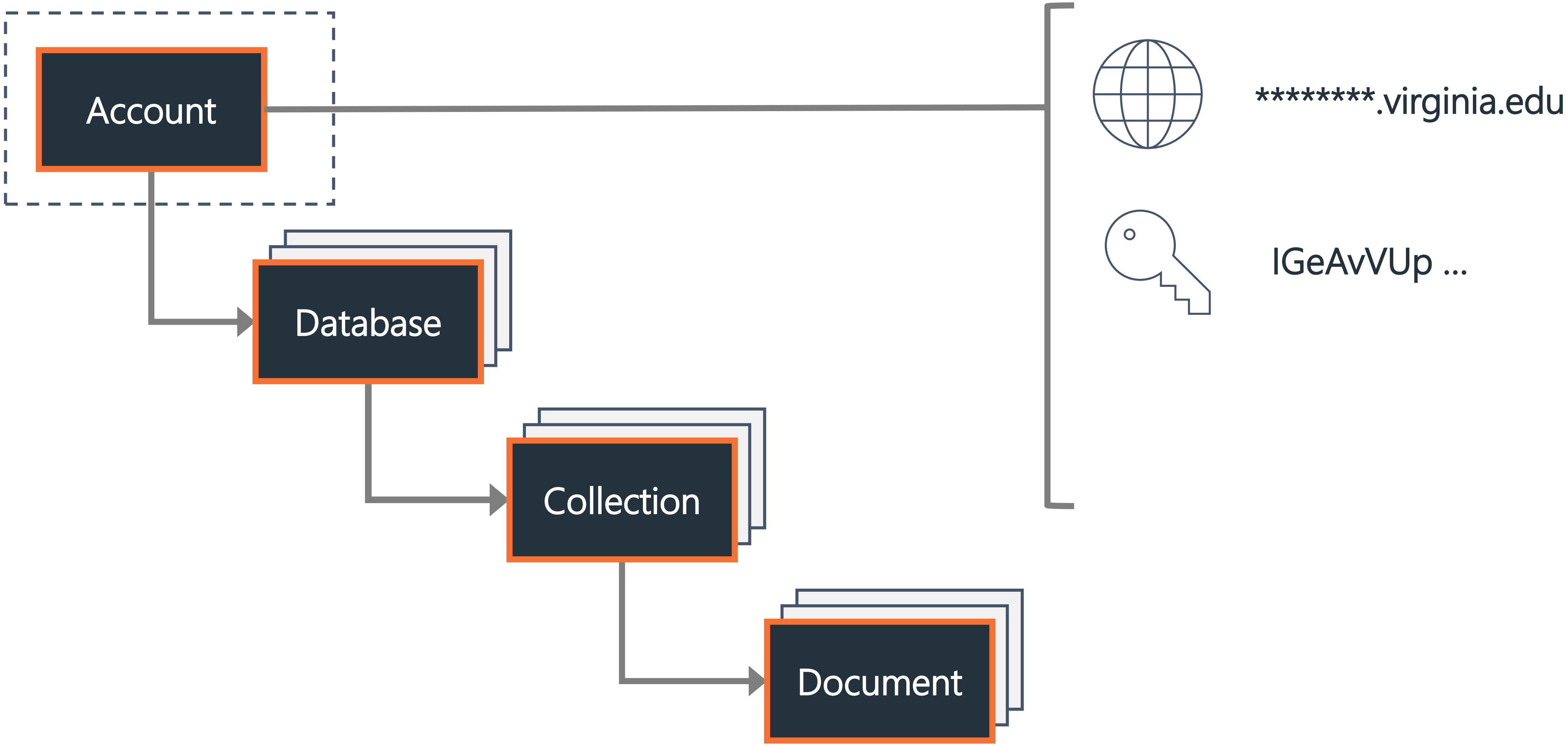
RDBMS and NoSQL Examples

RDBMS	NoSQL
MySQL	MongoDB
PostGreSQL	Amazon DynamoDB
SQL Server	Couchbase
Oracle	Neo4j
SQLite	Redis

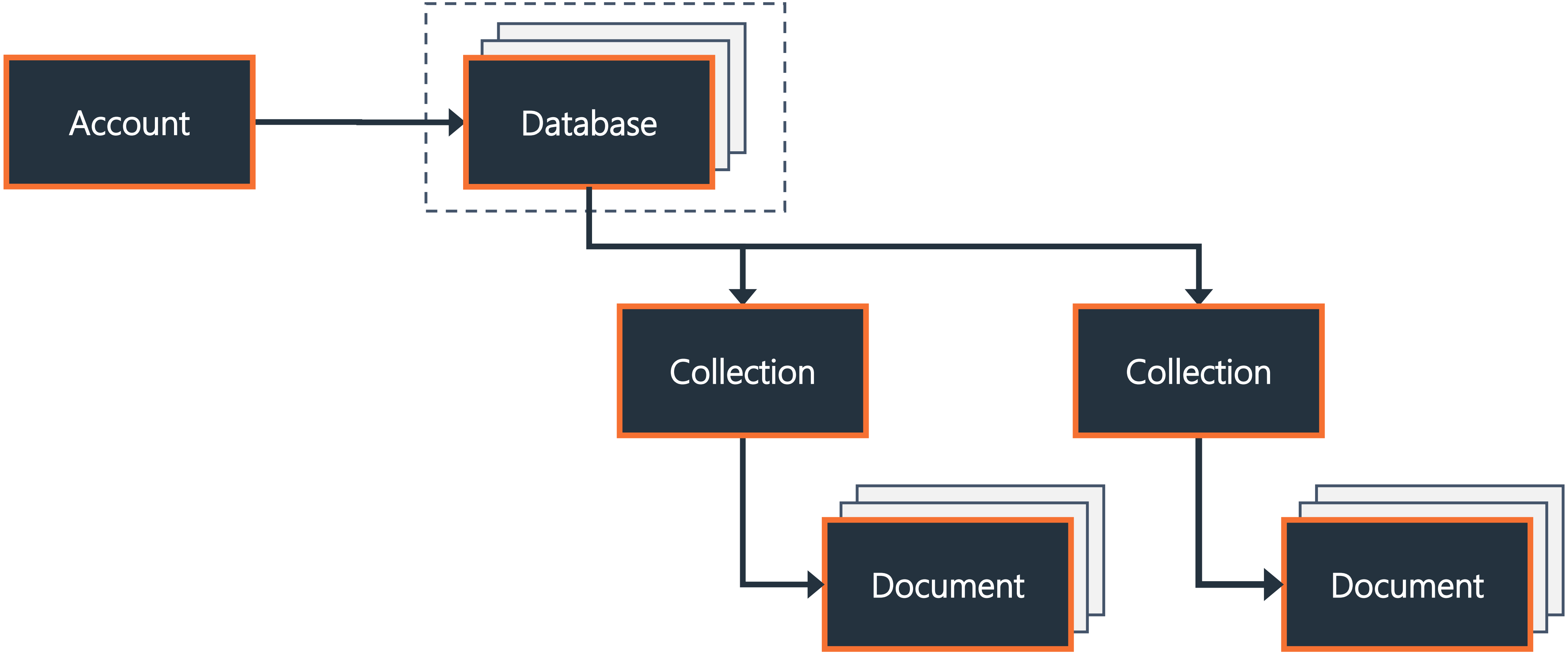
SQL versus NoSQL Databases

	SQL Databases	NoSQL Databases
Types	One: Relational Database	Many: Key-value, document, column, and graph databases
Data Storage	Records are stored as rows in tables that represent entities. Entity relationships are modeled by joining tables.	Records may be stored as "documents" using XML or JSON. Entity relationships are modeled by nesting them hierarchically.
Schemas	Static: Structure & data types are fixed at design time. Adding new elements requires schema design changes.	Dynamic: New elements can be added at runtime. Poly-schematic: Dissimilar data can be stored together as necessary.
Scaling	Vertically: A single server must be made increasingly powerful to cope with increasing demand.	Horizontally: New commodity servers and storage are added to an array. Data is automatically distributed across all servers.
Transactions	Full transactional consistency (ACID)	Single element (document) only.
Manipulation	Using platform-specific languages (SQL)	Using OSS API's, low-level lang., JavaScript
Consistency	Supports strong consistency	Per-product: Most are eventually consistent.

Resource Model: Account URI and Credentials



Resource Model: Database & Collection Resources



Document Collections versus Tables

JSON Documents
(Nested Hierarchies)

```
{
  "FirstName" : "Bob",
  "LastName" : "Smith",
  "BirthDate" : "03/11/1985",
  "PhoneNumbers" :
   [ { "Home" : "571-555-1212" },
     { "Cell" : "703-525-1234" } ],
  "Interests: [ "golf", "movies" ]
}
```

versus

RDBMS Tables
(Inter-tabular Relational Integrity)

Contacts

ContactID	123
FirstName	Bob
LastName	Smith
BirthDate	03/11/1985

Interests

InterestID	3
ContactID	123
Interest	Golf

PhoneNumbers

PhoneID	1
ContactID	123
Location	Home
Number	571-555-1212

Interacting with Data: Relational vs Document

Relational Databases
(SQL: Sequential Query Language)

- SELECT * FROM *[Table]* WHERE…
- INSERT INTO *[Table]* (Col1, Col1)
- UPDATE *[Table]* *SET [Col1] = 'value'*
- DELETE FROM *[Table]* *WHERE…*

Filtering: the WHERE clause

- WHERE LastName = 'Smith'
  AND InterestID IN (1,2)

Projection: the SELECT clause

- SELECT FirstName, LastName… FROM

versus

Document Collections
(Documents: JSON Expressions)

- db.*collection*.find({ *criteria* }, { *projection* })
- db.*collection*.insert({ *field* : *'value'* })
- db.*collection*.update({ *criteria* }, { *action* })
- db.*collection*.remove({ *criteria* })

Filtering: More JSON Documents

- { "LastName" : "Smith",
  "Interests" : {"Golf", "Movies"} }

Projection: More JSON Documents

- { "FirstName" : 1, "BirthDate" : 0,
  "PhoneNumbers.Home" : 1 }

Architectural Models: How They're Used

"Big Data" technologies aren't necessarily intended to replace existing database technologies; rather they play a critical role in extending the capabilities of a data management ecosystem.

Standalone Data Analysis and Visualization	Experiment with data sources to discover if they provide useful information. Handle data that can't be processed using existing systems.
Data Transfer, Cleansing or ETL	Extract and transform data before loading it into existing databases. Categorize, normalize, and extract summary results to remove duplication and redundancy.
Data Warehouse or Data Storage	Create robust data repositories that are reasonably inexpensive to maintain. Especially useful for storing and managing huge data volumes.
Integrate with Existing EDW and BI Systems	Integrate Big Data at different levels; EDW, OLAP, Excel PowerPivot. Also, APS enables querying Hadoop to integrate Big Data with existing dimension & fact data.

Document = BSON Document

- BSON simply stands for “Binary JSON”
- Based in Open JSON document format
- Extended to add some optional non-JSON-native data types.
- MongoDB stores data in BSON format both internally, and over the network

```json
{
  "InvoiceID": "IN1241287",
  "TotalItems": 9,
  "TotalValue": 52.15,
  "Customer": {
    "CSID": 112423532,
    "FullName": "Fred Flaire"
  },
  "Lines": [
    {
      "ProductCode": 63137,
      "Description": "Formal Work Pants (M)",
      "Quantity": 1,
      "Price": 42.43,
      "Size": 32,
      "Color": "Black"
    },
    {
      "ProductCode": 63137,
      "Description": "KitKat Jumbo",
      "Quantity": 8,
      "Price": 2.34,
      "Pack": 6,
      "Units": "Bars"
    }
  ]
}
```

Document = BSON Document

- Open JSON standard document format
- Language-independent data format
- Made up of attribute–value pairs
- Supports recursive embedding
- Supports embedded arrays
- Flexible schema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```

Items = JSON Document

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    }
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```
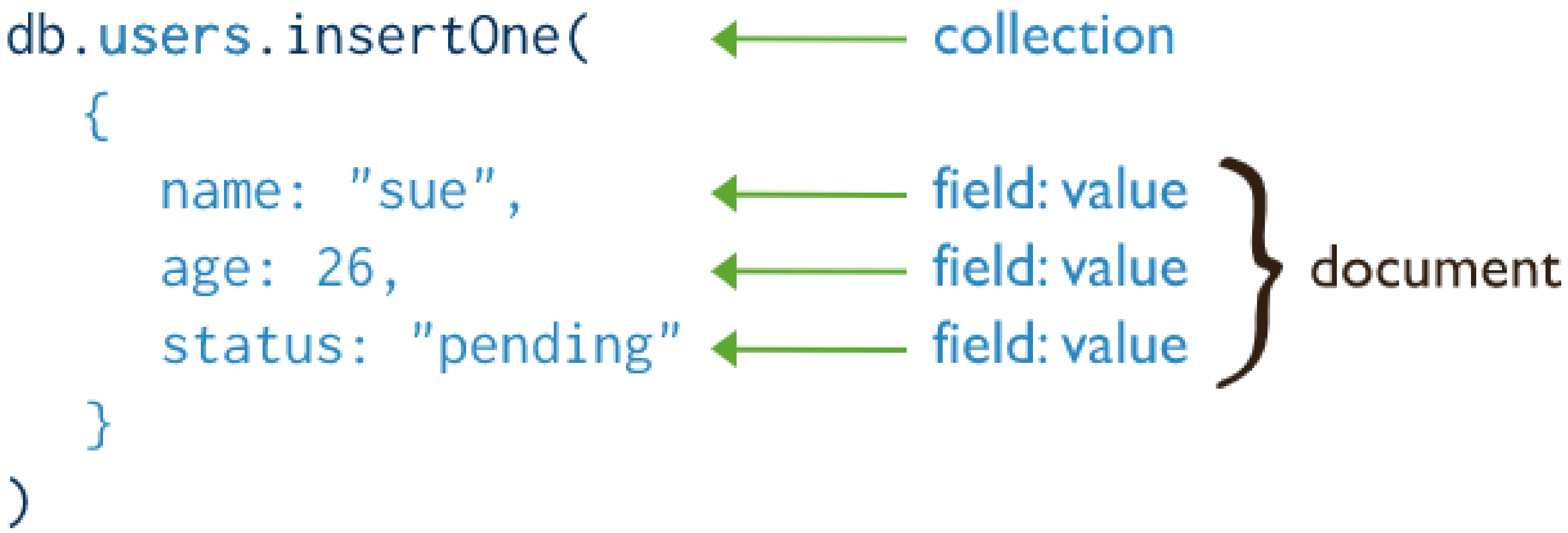

MongoDB API CRUD operations - Insert



MongoDB API CRUD operations - Read

`db.users.find(`	collection
`    { age: { $gt: 18 } },`	query criteria
`    { name: 1, address: 1 }`	projection
`).limit(5)`	cursor modifier

Features in MongoDB API – Indexing

Single Field Indexes: **db.coll.createIndex({name:1})**

Compound indexes: **db.coll.createIndex({name:1,age:1})**

Geospatial Indexes: **db.coll.createIndex({ location : "2dsphere" })**

Wildcard Indexes: **db.coll.createIndex({ "$**" : 1 })**

Features in MongoDB API – Creating databases

```
db.runCommand({customAction: "CreateDatabase"});

db.runCommand({customAction: "CreateDatabase", offerThroughput: 1000 });

db.runCommand({customAction: "CreateDatabase",
        autoScaleSettings: { maxThroughput: 20000 } });

db.runCommand({customAction: "UpdateDatabase", offerThroughput: 1200 });
```

Features in MongoDB API – Creating collections

```
db.runCommand({
  customAction: "CreateCollection",
  collection: "testCollection", offerThroughput: 400 });

db.runCommand({
  customAction: "UpdateCollection",
  collection: "testCollection", offerThroughput: 1200 });
```

Q & A

A Survey of Data Management Systems

The JSON Language

Understanding the Structured Query Language

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