Introduction to NoSQL Databases

NoSQL databases are a category of database systems designed to handle and store large volumes of structured, semi-structured, or unstructured data in ways that relational databases (SQL databases) cannot efficiently manage. The term "NoSQL" stands for "Not Only SQL," indicating that these databases can handle diverse data types and querying methods.

Key Features of NoSQL Databases

1. **Schema Flexibility:**
    - Unlike traditional relational databases, NoSQL databases do not require a predefined schema. This makes them ideal for dynamic, unstructured, or rapidly changing data.
2. **Horizontal Scalability:**
    - Designed to scale out by distributing data across multiple servers, making them well-suited for handling big data and high-traffic applications.
3. **High Performance:**
    - Optimized for fast data reads and writes, making them suitable for real-time applications.
4. **Distributed Architecture:**
    - NoSQL databases are inherently distributed, ensuring data availability and fault tolerance across multiple nodes.
5. **Varied Data Models:**
    - Support different types of data models, enabling better adaptability to specific application needs.

Installing and Configuring MongoDB

Here’s a detailed step-by-step guide to install and configure MongoDB on a Windows system.

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1. Download MongoDB

1. Visit the MongoDB Community Edition Download Page.
2. Select the appropriate version for Windows and download the .msi installer.

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2. Install MongoDB

1. **Run the Installer:**
   - Double-click the downloaded .msi file to launch the setup wizard.
2. **Choose Setup Type:**
   - Select "Complete" to install all features, including the MongoDB server and tools like mongosh.
3. **Service Configuration:**
   - Choose to run MongoDB as a Windows service (recommended).
   - Specify the data directory (default is C:\Program Files\MongoDB\Server\<version>\bin).
4. **Install Compass (Optional):**
   - During installation, you can opt to install MongoDB Compass, a graphical interface for MongoDB.
5. **Complete the Installation:**
   - Click "Install" to proceed. After the installation is complete, MongoDB will be available on your system.

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3. Configure MongoDB

Create Data and Log Directories

MongoDB requires specific directories to store data and logs:

1. Open File Explorer and create the following directories:
    - Data Directory: C:\data\db
    - Log Directory: C:\data\log

Create a Log File

1. Create an empty file mongod.log in C:\data\log.

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4. Start MongoDB

Option 1: Using Command Prompt

1. Open a command prompt.
2. Navigate to the MongoDB installation directory (e.g., C:\Program Files\MongoDB\Server\<version>\bin).
3. Start the MongoDB server:

```
mongod --dbpath "C:\data\db" --logpath "C:\data\log\mongod.log" --logappend --port 27017
```

Option 2: Run as a Windows Service

1. By default, MongoDB is installed as a service and starts automatically.
2. You can manually manage the service:
    - Start: net start MongoDB
    - Stop: net stop MongoDB

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5. Add MongoDB to System PATH

1. Add the bin folder of the MongoDB installation directory to the Windows PATH:
    - Example: C:\Program Files\MongoDB\Server\<version>\bin

2. This allows you to use MongoDB commands (mongod, mongosh) from any command prompt.

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6. Test MongoDB Installation

1. Open a command prompt.
2. Run the MongoDB shell:

```
mongosh
```

3. Verify the connection by running basic commands:

```
show dbs;
use testDB;
db.testCollection.insertOne({ name: "Test", type: "example" });
db.testCollection.find();
```

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7. Optional Configuration

Edit MongoDB Configuration File

1. Locate mongod.cfg (default: C:\Program Files\MongoDB\Server\<version>\bin\mongod.cfg).
2. Open it in a text editor and modify key settings as needed:
    - **Bind IP Address:** Allow MongoDB to accept remote connections:

```
net:
bindIp: 0.0.0.0
```

    - **Port:** Change the default port (27017) if required:

```
net:
port: 27017
```

    - **Enable Authentication:** Secure your database:

security:

authorization: enabled

3. Restart the MongoDB service for changes to take effect:

net stop MongoDB

net start MongoDB

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8. Access MongoDB via MongoDB Compass (Optional)

- If MongoDB Compass was installed:
  - Open MongoDB Compass.
  - Connect to the server (default: localhost:27017).

By following these steps, MongoDB will be installed and configured on your Windows system, ready for development or production use.

CRUD Operations in MongoDB

CRUD stands for **Create**, **Read**, **Update**, and **Delete**—the fundamental operations for interacting with any database. In MongoDB, these operations are performed on collections (analogous to tables in relational databases) and documents (analogous to rows in relational databases).

Here's a breakdown of how to perform CRUD operations using the MongoDB shell (mongosh) or any MongoDB client.

1. **1. Create Operations**

Create operations add new documents to a collection.

Insert a Single Document

db.collection.insertOne({ name: "John", age: 25, city: "New York" });

Insert Multiple Documents

```
db.collection.insertMany([ { name: "Alice", age: 30, city: "London" },
{ name: "Bob", age: 22, city: "Paris" }
]);
```

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2. Read Operations

Read operations retrieve data from collections.

Find All Documents

```
db.collection.find();
```

Find Documents with a Query

Use a query object to filter results:

```
db.collection.find({ city: "New York" });
```

Find One Document

```
db.collection.findOne({ name: "John" });
```

Format Output (Pretty Print)

```
db.collection.find().pretty();
```

Projection (Select Specific Fields)

```
db.collection.find({ city: "London" }, { name: 1, age: 1, _id: 0 });
```

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3. Update Operations

Update operations modify existing documents.

Update a Single Document

```
db.collection.updateOne(
{ name: "John" }, // Filter
```

{ $set: { age: 26 } } // Update

);

Update Multiple Documents

db.collection.updateMany({ city: "London" }, // Filter

{ $set: { country: "UK" } } // Update

);

Replace a Document

Replace an entire document:

db.collection.replaceOne({ name: "Alice" }, // Filter

{ name: "Alice", age: 35, city: "Berlin" } // New document

);

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4. Delete Operations

Delete operations remove documents from collections.

Delete a Single Document

db.collection.deleteOne({ name: "John" });

Delete Multiple Documents

db.collection.deleteMany({ city: "London" });

Drop an Entire Collection

Remove all documents and the collection itself:

db.collection.drop();

CRUD Operations Example

Let’s see an example that combines all four operations:

Step 1: Insert Documents

```
db.users.insertMany([
{ name: "Emma", age: 28, city: "New York" },
{ name: "Liam", age: 35, city: "London" },
{ name: "Sophia", age: 22, city: "Paris" }
]);
```

Step 2: Read Documents

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

Step 3: Update Documents

```
db.users.updateOne({ name: "Emma" }, { $set: { age: 29 } });
```

Step 4: Delete a Document

```
db.users.deleteOne({ name: "Sophia" });
```

CRUD Operations Using Drivers

If you're using MongoDB drivers (e.g., Python, Node.js), CRUD operations are performed similarly by calling corresponding methods
like insert_one, find, update_one, and delete_one on the collection object. Let me know if you'd like specific examples for a programming language!

Indexing and Querying in MongoDB

Indexing and querying are fundamental features in MongoDB that help retrieve and manage data efficiently. Here's a detailed guide on how they work and how to implement them.

1. Indexing in MongoDB

Indexes are special data structures that store a small portion of the collection's data in an easy-to-traverse format. They improve the speed of query execution.

Default Index

- MongoDB automatically creates an _id index for every document, which ensures uniqueness and fast lookups based on the _id field.

Types of Indexes

1. **Single Field Index:**
    - Creates an index on a single field.

```
db.collection.createIndex({ fieldName: 1 }); // 1 for ascending, -1 for descending
```

2. **Compound Index:**
    - Creates an index on multiple fields.

```
db.collection.createIndex({ field1: 1, field2: -1 });
```

3. **Multikey Index:**
    - Indexes array fields.

```
db.collection.createIndex({ arrayField: 1 });
```

4. **Text Index:**
    - Enables text search for strings.

```
db.collection.createIndex({ fieldName: "text" });
```

5. **Geospatial Index:**
    - Used for querying geographical coordinates.

```
db.collection.createIndex({ location: "2dsphere" });
```

6. **Unique Index:**
    - Ensures all indexed values are unique.

```
db.collection.createIndex({ fieldName: 1 }, { unique: true });
```

7. **TTL (Time-to-Live) Index:**
    - Automatically removes documents after a specified period.

```
db.collection.createIndex({ createdAt: 1 }, { expireAfterSeconds: 3600 });
```

Managing Indexes

1. **View Indexes:**

```
db.collection.getIndexes();
```

2. **Drop an Index:**

```
db.collection.dropIndex("indexName");
```

3. **Drop All Indexes:**

```
db.collection.dropIndexes();
```

2. Querying in MongoDB

MongoDB provides a flexible query language for retrieving data. Queries are performed using the find() method.

Basic Queries

1. **Find All Documents:**

```
db.collection.find();
```

2. **Find with Filters:**

```
db.collection.find({ fieldName: value });
```

3. **Find Specific Fields (Projection):**

```
db.collection.find({ fieldName: value }, { field1: 1, field2: 0 }); // 1 to include, 0 to exclude
```

1. **Query Operators**

1. **Comparison Operators:**

```
db.collection.find({ age: { $gt: 18 } }); // Greater than
db.collection.find({ age: { $gte: 18 } }); // Greater than or equal
db.collection.find({ age: { $lt: 30 } }); // Less than
db.collection.find({ age: { $lte: 30 } }); // Less than or equal
db.collection.find({ age: { $ne: 25 } }); // Not equal
db.collection.find({ age: { $in: [18, 25, 30] } }); // In array
db.collection.find({ age: { $nin: [18, 25] } }); // Not in array
```

2. **Logical Operators:**

```
db.collection.find({ $and: [{ age: { $gt: 18 } }, { city: "London" }] });
db.collection.find({ $or: [{ age: { $lt: 18 } }, { city: "Paris" }] });
db.collection.find({ $not: { age: { $gte: 18 } } });
```

3. **Element Operators:**

```
db.collection.find({ fieldName: { $exists: true } }); // Field exists
db.collection.find({ fieldName: { $type: "string" } }); // Field is of type
```

4. **Array Operators:**

```
db.collection.find({ tags: { $all: ["tag1", "tag2"] } }); // Match all elements
db.collection.find({ tags: { $size: 2 } }); // Array size
db.collection.find({ tags: { $elemMatch: { key: "value" } } }); // Match specific element
```

5. **Regular Expressions:**

```
db.collection.find({ name: /john/i }); // Case-insensitive search
```

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2. **Sorting, Limiting, and Skipping**

1. **Sort Results:**

```
db.collection.find().sort({ age: 1 }); // 1 for ascending, -1 for descending
```

2. **Limit Results:**

```
db.collection.find().limit(5);
```

3. **Skip Results:**

```
db.collection.find().skip(5);
```

4. **Combine Sort, Limit, and Skip:**

```
db.collection.find().sort({ age: -1 }).limit(5).skip(10);
```

Schema Design in MongoDB

1. **Application Requirements:**
    - Understand the application's query patterns, data relationships, and performance needs.
2. **Read vs. Write Optimization:**
    - Decide whether the schema should prioritize faster reads (denormalization) or writes (normalization).
3. **Data Relationships:**
    - Consider how entities are related and whether to use **embedding** or **referencing**.
4. **Data Growth and Scalability:**
    - Plan for scaling as the dataset grows, ensuring efficient sharding and indexing.
5. **Data Structure and Access Patterns:**
    - Optimize the schema based on how the data will be queried and updated.

Data Modeling in MongoDB

Data modeling in MongoDB involves designing the structure of your data to meet the application's performance, scalability, and functionality requirements. Unlike relational databases, MongoDB uses a flexible, document-based schema that can handle unstructured or semi-structured data efficiently.

Key Concepts in MongoDB Data Modeling

Document-Oriented Data Model

- MongoDB uses **documents** (key-value pairs) as the basic unit of data.
- Documents can be nested (hierarchical) and contain arrays, unlike rows in relational databases.
- Example of a document for a blog post:

```
json
{
    "_id": 1,
    "title": "Introduction to MongoDB",
    "author": { "name": "John", "email":
"john@example.com" },
    "tags": ["MongoDB", "Database", "NoSQL"],
    "comments": [
        { "user": "Jane", "comment": "Great
article!" },
        { "user": "Doe", "comment": "Very helpful,
thanks!" }
    ]
}
```

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2. Schema Design in MongoDB

MongoDB is **schema-less**, meaning documents in a collection do not require a predefined structure. However, defining a schema helps ensure data consistency.

- **Flexible Schema**: You can add new fields to documents without affecting other documents in the collection.

- **Example**:

```
json
// Document 1
{ "name": "Alice", "age": 25 }

// Document 2 (with additional fields)
{ "name": "Bob", "age": 30, "address": "New York" }
```

---

3. Embedding vs. Referencing Relationships

MongoDB allows you to represent relationships between data in two main ways:

a) Embedded Data (Denormalized)

- Store related data **inside the parent document** as a subdocument.
- Suitable for **one-to-few** relationships where child data is always accessed with the parent.
- Example:

```
json
{
    "name": "Product A",
    "category": "Electronics",
    "reviews": [
        { "user": "Alice", "rating": 5 },
        { "user": "Bob", "rating": 4 }
    ]
}
```

b) Referenced Data (Normalized)

- Store related data in **separate collections** and reference them using foreign keys.
- Suitable for **one-to-many** or **many-to-many** relationships.
- Example:
    - **Products Collection**:

```
json
```

```
{ "_id": 1, "name": "Product A", "category":
"Electronics" }
```

- **Reviews Collection**:

```
json
Copy code
{ "product_id": 1, "user": "Alice", "rating":
5 }
{ "product_id": 1, "user": "Bob", "rating": 4 }
```

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4. Data Modeling Strategies

a. One-to-One Relationship

- Embed the related document inside the parent document.
- Example:

```
json
{
    "user_id": 1,
    "name": "John",
    "profile": { "email": "john@example.com", "age":
30 }
}
```

b. One-to-Many Relationship

- **Embed** for small datasets: Store subdocuments in an array.
- **Reference** for large datasets: Use a separate collection.
- Example (embedded):

```
json
Copy code
{
    "post_id": 1,
    "title": "MongoDB Guide",
    "comments": [
        { "user": "Alice", "comment": "Great!" },
        { "user": "Bob", "comment": "Thanks!" }
```

```
        ]
    }
```

c. Many-to-Many Relationship

- Use **referencing** to connect documents in two collections.
- Example:
  - Users Collection:

    ```
    json
    { "_id": 1, "name": "Alice" }
    ```

  - Courses Collection:

    ```
    json
    Copy code
    { "_id": 101, "course_name": "MongoDB Basics" }
    ```

  - Enrollment Collection:

    ```
    json
    Copy code
    { "user_id": 1, "course_id": 101 }
    ```

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5. Aggregation Framework

MongoDB's **Aggregation Framework** allows you to process and transform data in collections.

- You can use operators like `$group`, `$match`, `$lookup`, and `$unwind`.
- Example: Join referenced data using `$lookup` for a many-to-many relationship.

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6. Data Redundancy

- In MongoDB, it is sometimes acceptable to duplicate data to improve query performance.

- Redundancy reduces the need for joins, which can be expensive in NoSQL databases.