Database Basics

Database Management Systems and SQL

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Table of Contents

Databases: Introduction

Data Storage and Data Management

What is a Database?

- A **database** is a collection of data, organized to be easily accessed, managed and updated
- Modern databases are managed by **Database Management Systems** (DBMS)
  - Define database **structure**, e.g. tables, collections, columns, relations, indexes
  - Create / Read / Update / Delete data (CRUD operations)
  - Execute **queries** (filter / search data)

Relational and NoSQL Databases

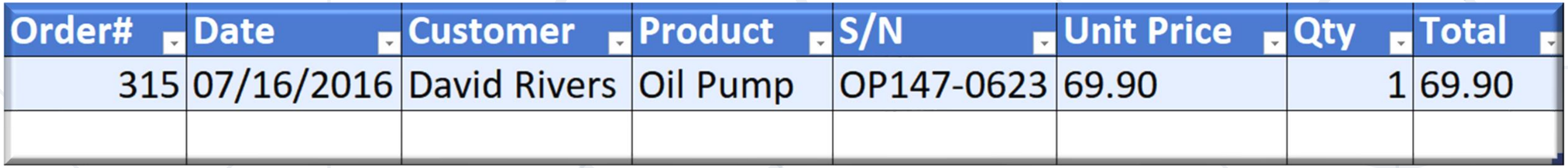
- Databases hold and manage data in the back-end systems
- **Relational databases** (RDBMS)
  - Hold data in **tables** + **relationships**
  - Use the **SQL** language to query / modify data
  - Examples: MySQL, PostgreSQL, Web SQL in HTML5
- **NoSQL databases**
  - Hold **collections** of documents or key-value pairs
  - Examples: MongoDB, IndexedDB in HTML5

Data Storage

- Conventional data storage
  - Orders
  - Receipts

From Data Storage to Databases

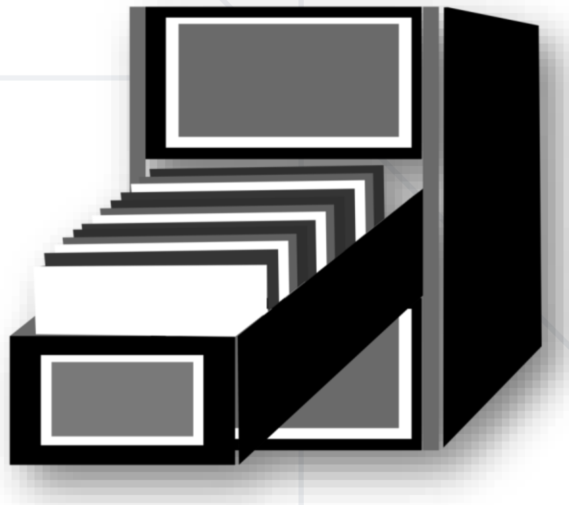
- We can **group related pieces of data** into separate columns:



Order#	Date	Customer	Product	S/N	Unit Price	Qty	Total
315	07/16/2016	David Rivers	Oil Pump	OP147-0623	69.90	1	69.90

Why Do We Need Databases?

- Storing data is **not** the primary reason to use a database
- Flat storage runs into **issues** with
  - Ease of searching
  - Ease of updating
  - Performance
  - Accuracy and consistency
  - Security and access control
  - Redundancy



SQL vs. NoSQL Databases

SQL Databases (Relational Databases)

- Relational (**SQL**) databases organize data in **tables**
  - Tables have strict structure (**columns** with certain **data types**)
  - Can have **relationships** to other tables

- Relational databases use the **structured query language** (SQL) for defining and manipulating data
  - Extremely powerful for complex queries
- **Relational databases** are the most widely used data management technology

SQL Databases (Relational Databases)

- Relational DB model organizes data into one or more **tables** of columns and rows with a **unique key** identifying each row and **foreign keys** defining **relationships**

Items

ID	Order ID	Name	Quantity	Price
5	1	Table	1	200.00
6	1	Chair	1	123.12

Customers

ID	Name	Email
5	Peter	peter@gmail.com
6	Jayne	jayne@gmail.com

Orders

ID	Customer ID	Date	Total Price
1	5	11/1/17	323.12
2	1	11/15/17	13.99

NoSQL Databases (Non-Relational Databases)

- A **NoSQL** databases have dynamic schema for **unstructured** data
- Data is stored in many ways
  - Document-oriented
  - Column-oriented
  - Graph-based
  - Key-value store

Scalability: Relational vs. NoSQL

- SQL are **vertically** scalable
  - You can increase the load on a single server by **increasing its resources** (CPU, RAM, SSD)
  - Or you can **replicate the data** to a cluster of several servers
- NoSQL are **horizontally** scalable
  - You handle more traffic by **sharding** and adding more servers in your NoSQL database cluster

Structure: Relational vs. NoSQL

- SQL databases are **table-based**
- Better option for:
  - Applications that require multi-row transactions, such as an accounting system
  - Complex transaction processing systems

- SQL databases hold **dynamic data**
- NoSQL databases implement **four main data models**
  - Document store
  - Wide-column store
  - Key-value data store
  - Graph store

DBMS Systems: Examples

- **SQL databases** examples
  - MySQL
  - PostgreSQL
  - Oracle
  - Microsoft SQL Server
  - SQLite and Web SQL
- **NoSQL databases** examples
  - MongoDB
  - Redis
  - Google BigTable
  - Amazon DynamoDB
  - Azure Cosmos DB
  - Cassandra

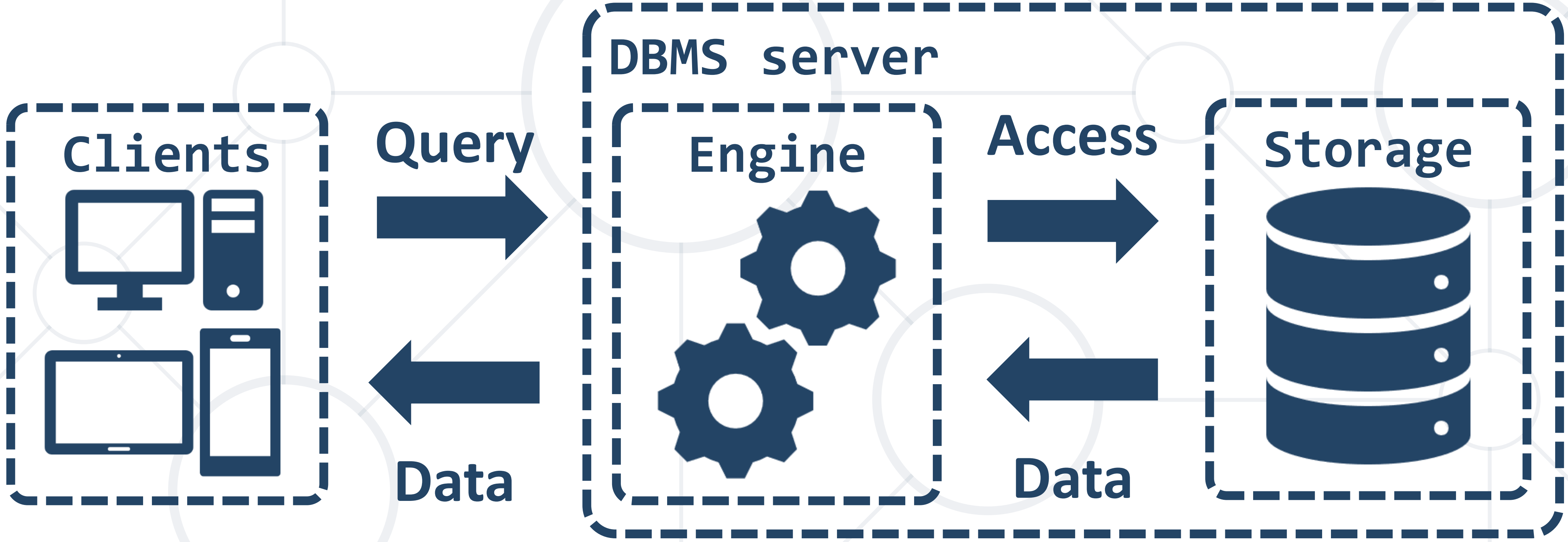
Database Management Systems (DBMS)

Database Management Systems (DBMS)

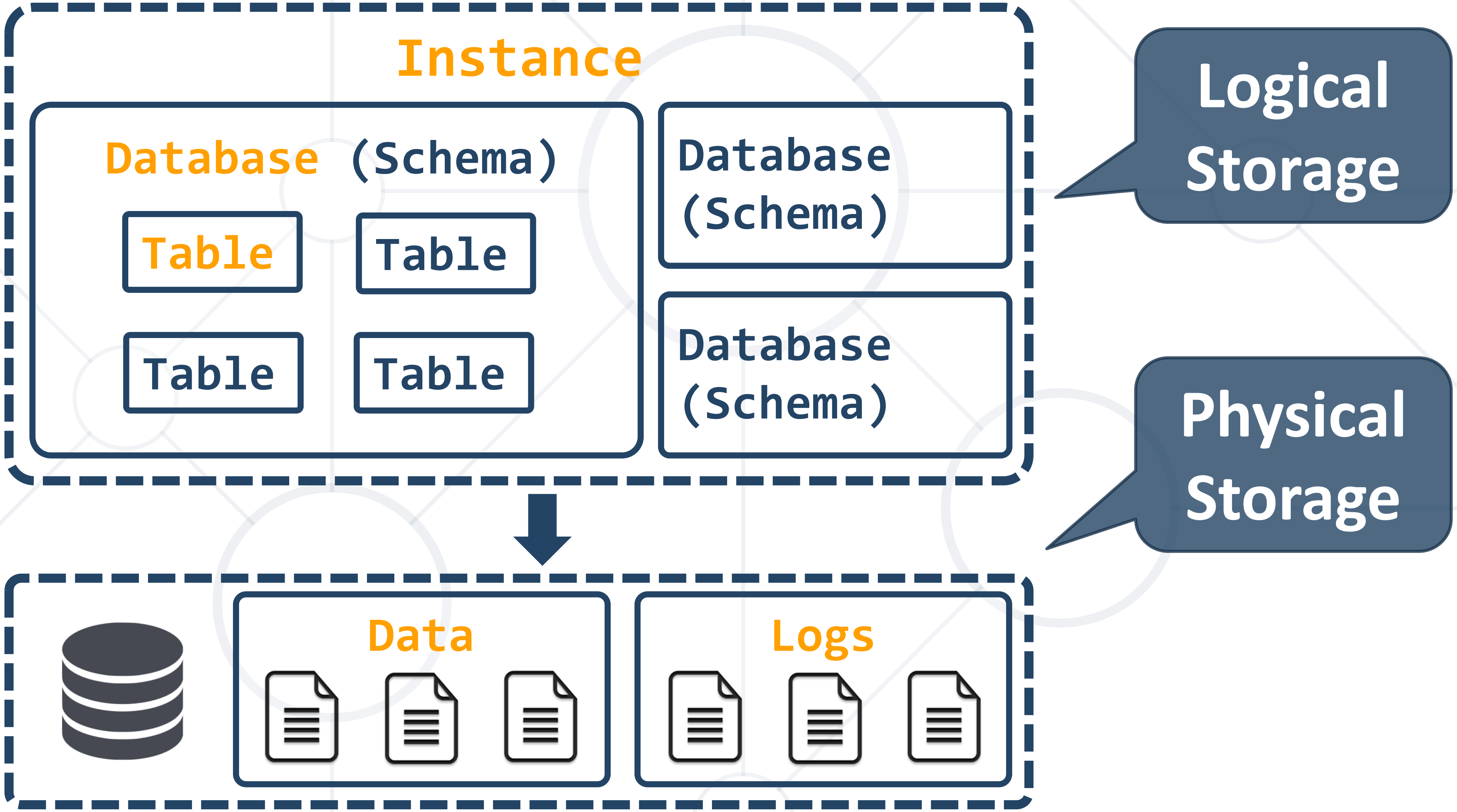
- A Database Management System (**DBMS**) is a software, used to **define**, **manipulate**, **retrieve** and **manage** data in a database
- DBMS generally **manipulates** the data itself, the data format, field names and data types, record structure and file structure
- DBMS examples
  - MySQL, MS SQL Server, Oracle, PostgreSQL
  - MongoDB, Cassandra, Redis, HBase
  - Amazon DynamoDB, Azure Cosmos DB

DBMS Systems and Data Flow

- DBMS servers use the **client-server model**:



DBMS Server Architecture

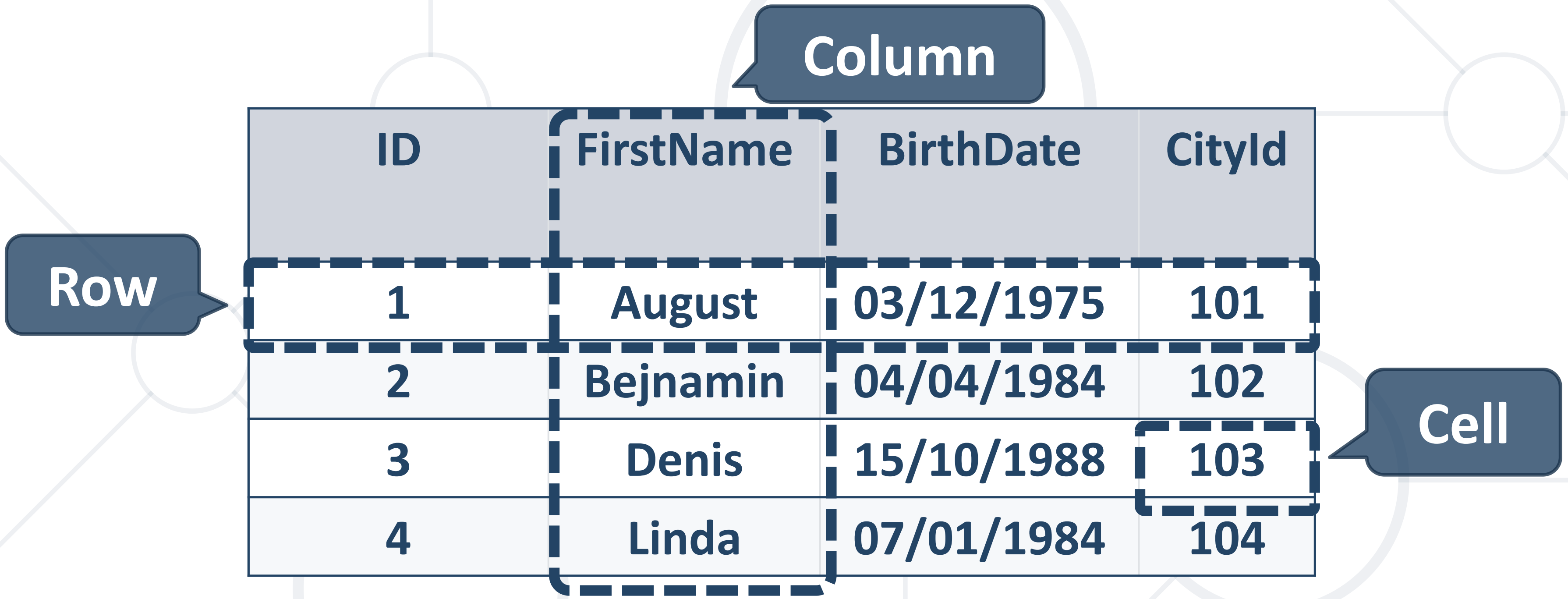


Relational Databases

RDBMS, the SQL Language and MySQL Database

Database Table Elements

- The **table** is the main **building block** in the relational databases



ID	FirstName	BirthDate	CityId
1	August	03/12/1975	101
2	Bejnamin	04/04/1984	102
3	Denis	15/10/1988	103
4	Linda	07/01/1984	104

- Each **row** is called a **record** or **entity**
- Columns (**fields**) define the **type** of data they contain

Structured Query Language (SQL)

- **SQL** == query language designed for managing data in **relational** databases (RDBMS)
  - Used to communicate with the database engine
- Logically, SQL is divided into four sections
  - **Data definition**: describe the **structure** of data
  - **Data manipulation**: **store** and **retrieve data**
  - **Data control**: define who can **access the data**
  - **Transaction control**: bundle **operations** together and perform **commit** / **rollback**

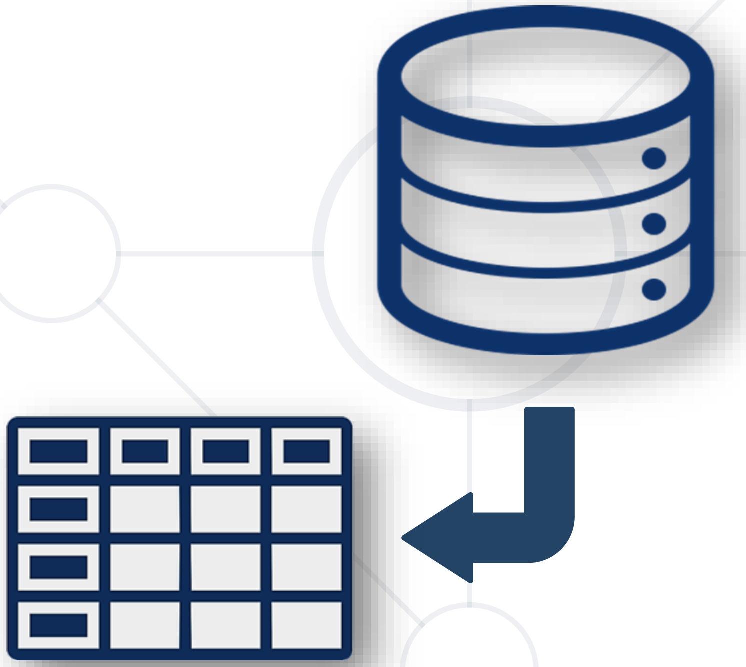
SQL – Example

- Example of SQL query

```
SELECT * FROM people
```

- The query is executed by the DBMS system
  - It returns a sequence of data rows, e.g.,

id	email	first_name	last_name
1	smith@yahoo.co.uk	John	Smith
2	pwh@gmail.com	Peter	White
3	anne@anne.com	Anne	Green
4	jason.jj@gmail.com	Jason	Anderson



MySQL / MariaDB

- **MySQL** == **open-source** relational database management system (RDBMS), very popular, also known as MariaDB
  - Runs on **most** server platforms: Linux, Windows, macOS
- Used in many **large-scale** software projects
  - Amazon, Apple, Facebook, others
- In MySQL data is stored in **tables** with **relationships** between them
  - SQL is used to query / manipulate data

Developer Tools for MySQL

- phpMyAdmin (part of XAMPP)
  - **phpMyAdmin** is Web-based MySQL admin tool
  - **XAMPP** == Web server development stack
    - Apache + MariaDB + PHP + phpMyAdmin
- HeidiSQL
  - GUI tool for managing MySQL, MSSQL and PostgreSQL
  - Query / modify database
  - Explore database objects

SQL Commands

- We can **communicate** with the database engine via **SQL**
- SQL commands provide greater **control** and **flexibility**
- To **create** a database in MySQL

```
CREATE DATABASE employees
```

Database name

- **Display** all databases in MySQL

```
SHOW DATABASES
```

Creating Table and Inserting Values

- **Creating** tables

Table name

```
CREATE TABLE people (
   id INT NOT NULL PRIMARY KEY AUTO_INCREMENT,
   email VARCHAR(40) NOT NULL,
   first_name VARCHAR(40) NOT NULL,
   last_name VARCHAR(40) NOT NULL
)
```

Primary key definition

Column name

Data type

- **Inserting** values

```
INSERT INTO people(email, first_name, last_name)
VALUES ('john@gmail.com', 'John', 'Smith')
```

Retrieving Records

- **Retrieve** all records from a table

```
SELECT * FROM people
```

* retrieves all columns

- You can **limit** (select) **the columns** to retrieve

```
SELECT first_name, last_name FROM people
```

List of columns

- You can **limit the number of rows**

```
SELECT first_name, last_name FROM people
LIMIT 5
```

Number of rows to return

Filtering Data

- Retrieve all records, matching a **filter**

```
SELECT * FROM people
WHERE email = 'peter@gmail.com'
```

Filter the returned rows by a condition

- **Filter** and **sort** data

```
SELECT * FROM people
WHERE id > 10 AND id < 20
ORDER BY id
```

Filter by multiple conditions

Sort by given column / expression

Updating Records

- **Updating** rows

```
UPDATE people
SET last_name = 'Adams'
WHERE first_name = 'John'
```

Updates the last name of person

```
UPDATE people
SET first_name = 'Peter',
    last_name = 'White',
    email = 'pw@email.com'
WHERE id = 42
```

Update multiple fields

Deleting Data and Objects

- **Deleting** table rows

```
DELETE FROM people WHERE id = 42
```

- Deleting (**dropping**) database objects
  - Table

Delete all records in a table

```
TRUNCATE TABLE people
```

Delete the table itself

```
DROP TABLE people
```

  - Entire database

```
DROP DATABASE employees
```

  - These actions **cannot be undone**

NoSQL Databases

Using MongoDB

NoSQL Databases

- **NoSQL databases** don't use tables and SQL
  - Instead, use **document collections** or **key-value pairs**
- More **scalable** and provide **superior performance**
- Examples: **MongoDB**, **Cassandra**, **Redis**, etc.

```
{
  ObjectId("59d3fe7ed81452db0933a871"),
  "email": peter@gmail.com,
  "age": 22
}
```

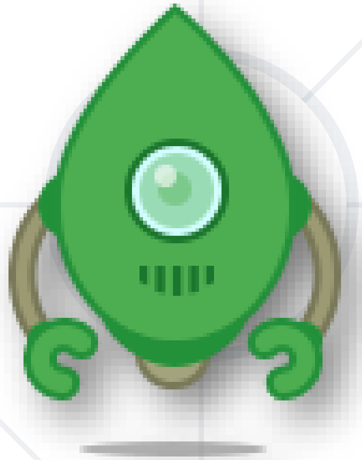
Example of JSON document in MongoDB

MongoDB

- **MongoDB** == free **open-source** cross-platform **document-oriented database**
  - Keeps collections of **JSON** documents (with or without schema)
- Sample usages: **mobile app** backend, product **catalog**, **poll** system, **blog** system, Web content management system (**CMS**)
- Supports evolving data requirements
  - The DB structure **may change** over the time
- Supports **indexing** for increased performance

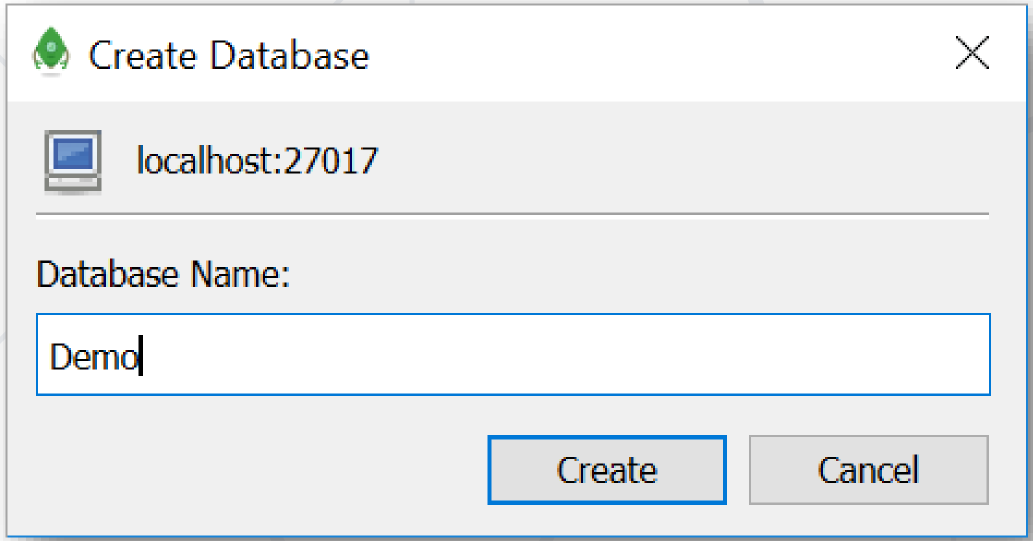
Developer Tools for MongoDB

- **MongoDB Compass**
- **Robo 3T**
  - Powerful **GUI tool** for MongoDB
  - Fully-featured IDE with embedded **shell**
- **NoSQLBooster** (alternative)
  - Shell-centric cross-platform GUI tool
  - Object explorer and query builder



Creating a Database

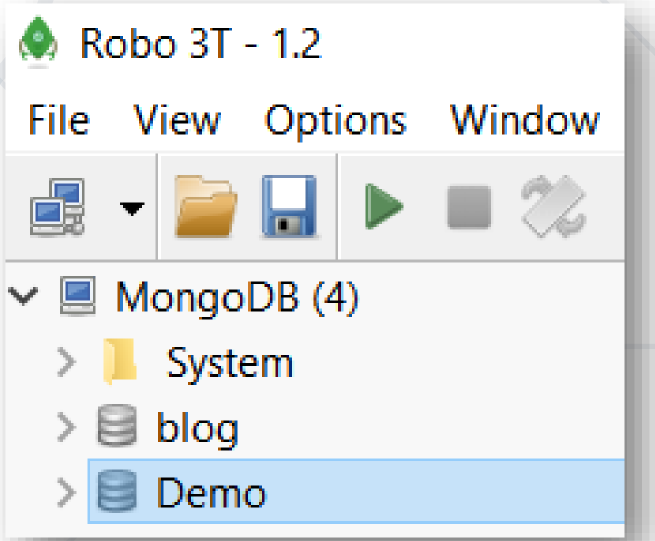
- **Creating a MongoDB database** in Robo 3T is done using the GUI
- Right click on [**New Connection**] and select [**Create Database**]


Create Database

localhost:27017

Database Name:

Demo



Creating a Collection and Inserting Values

- **Creating a collection**

```
db.createCollection('people')
```

Collection name

- **Inserting a document** to existing collection

```
db.getCollection('people')
   .insert({
       firstName: 'Michael',
       lastName: 'Smith',
       email: 'michael@gmail.com'
})
```

Data is inserted as **JSON object**

Retrieve Entries

- Get **all entries** from a collection

```
db.getCollection('people').find({})
```

- Filter elements by **given criteria**

```
db.getCollection('people').find({ firstName: 'Michael' })
```

- Return **specified** fields

```
db.getCollection('people').find(
  { firstName: 'Michael' },
  { lastName: 1 }
)
```

Retrieves an **entity** with the desired **fields only**

Updating Entries

- Update the **first** entry

```
db.getCollection('people').updateOne(
  { firstName: 'Kate' },
  { $set:{ firstName: 'George', age: 25 } }
)
```

Old values (filter)

New object (replacement)

```
db.getCollection('people').updateOne(
  { firstName: 'Kate' },
  { $set: { firstName: 'George', lastName:
'Doe'} },
  { multi: true }
)
```

Update **all matching entries**

Deleting Entries

- Delete the **first entry** that matches given criteria

```
db.getCollection('people').deleteOne(
    { firstName: 'George' }
)
```

- Delete **all entries** that match given criteria

```
db.getCollection('people').deleteMany(
    { firstName: 'George' }
)
```

Summary

- Database management systems (DBMS) store and manage data
  - Developers communicate with the DB engine via SQL commands or via API
- MySQL is open-source RDBMS: data is stored in tables and accessed via SQL
- NoSQL databases are more flexible
  - MongoDB stores entries in JSON format

Questions?

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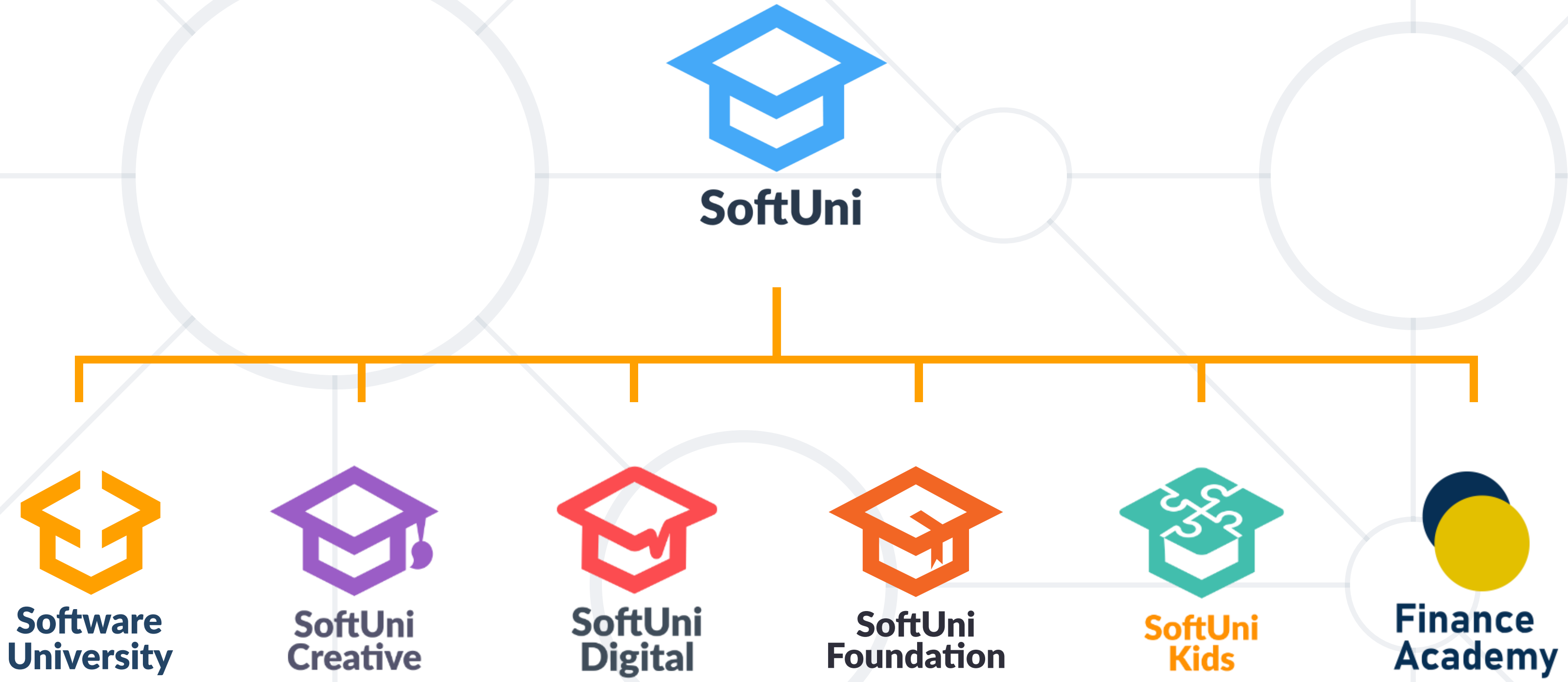

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