

INTRODUCTION TO DATABASES

Database Foundations

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2024-III



Outline

- 1 Software Components and Applications
- 2 Glosary
- 3 DataBase Classification
- 4 Relational Database Design
- 5 Entity-Relation Model (MER)
- 6 DataBase Management Systems — DBMS
- 7 DataBases Infrastructure
- 8 DevOps
- 9 Data Engineering



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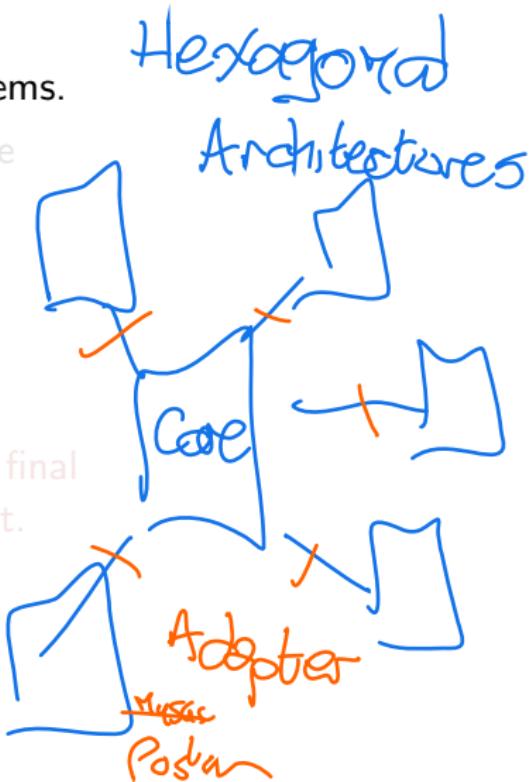
8 DevOps

9 Data Engineering



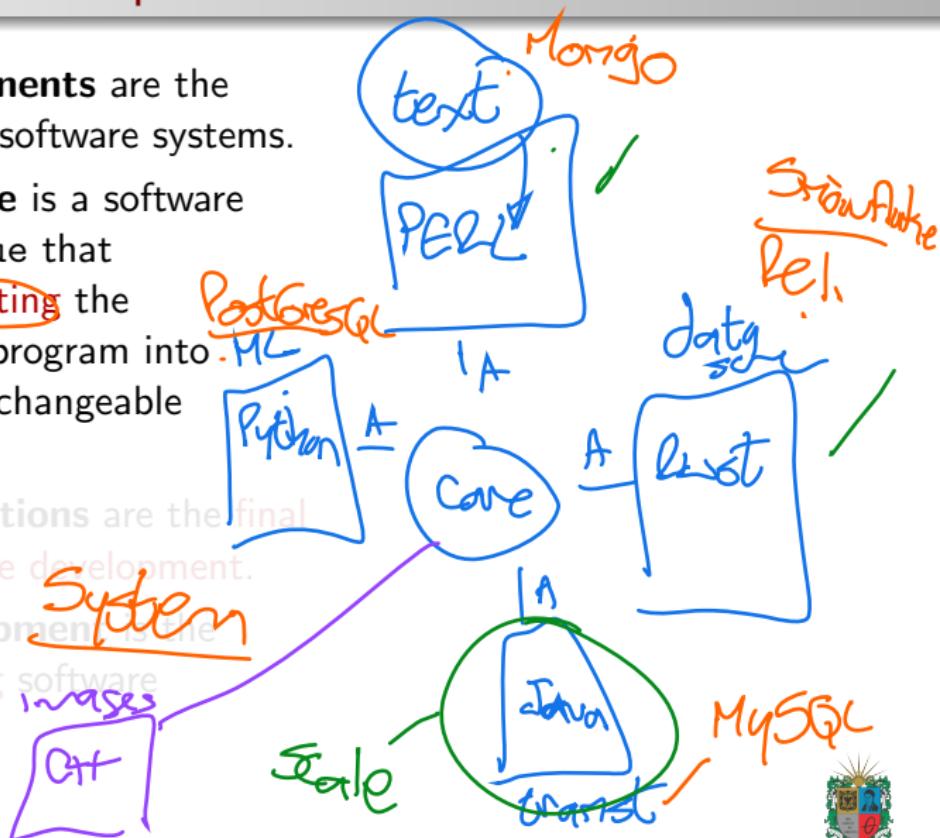
Modular Software Components

- **Software Components** are the building **blocks** of software systems.
- Modular Software is a software design technique that emphasizes **separating** the **functionality** of a program into independent, interchangeable **modules**.
- **Software Applications** are the final product of software development.
- **Software Development** is the process of creating software applications.



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Modular Software Components

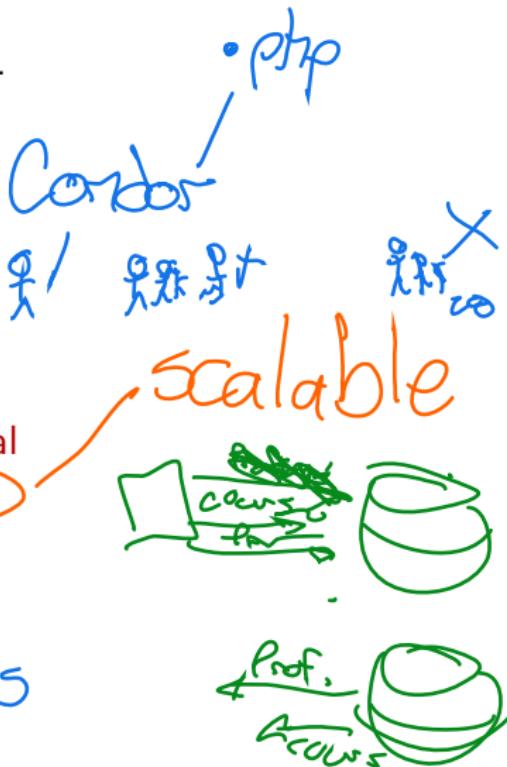
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Flexibility

black Friday

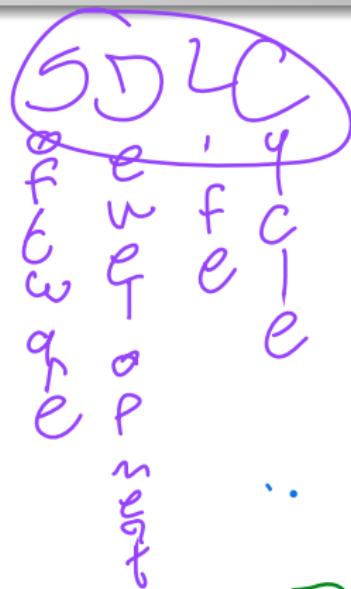
high demand

AWS



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History of Data

IOT \Rightarrow Ubiquitous
Pervasive / network

HISTORY OF DATA

19,000 BC



The Ishango bone holds the first evidence of data collection and storage.

1600s



John Graunt introduces the concept of data analysis in 1663.

1800s



Herman Hollerith designs a machine that helped complete the US census in 1890.

1900s



Fritz Pfleumer invents the magnetic tape which later inspired the invention of floppy disks and hard disk drives.

1990s



Sir Tim Berners Lee invents the World Wide Web.

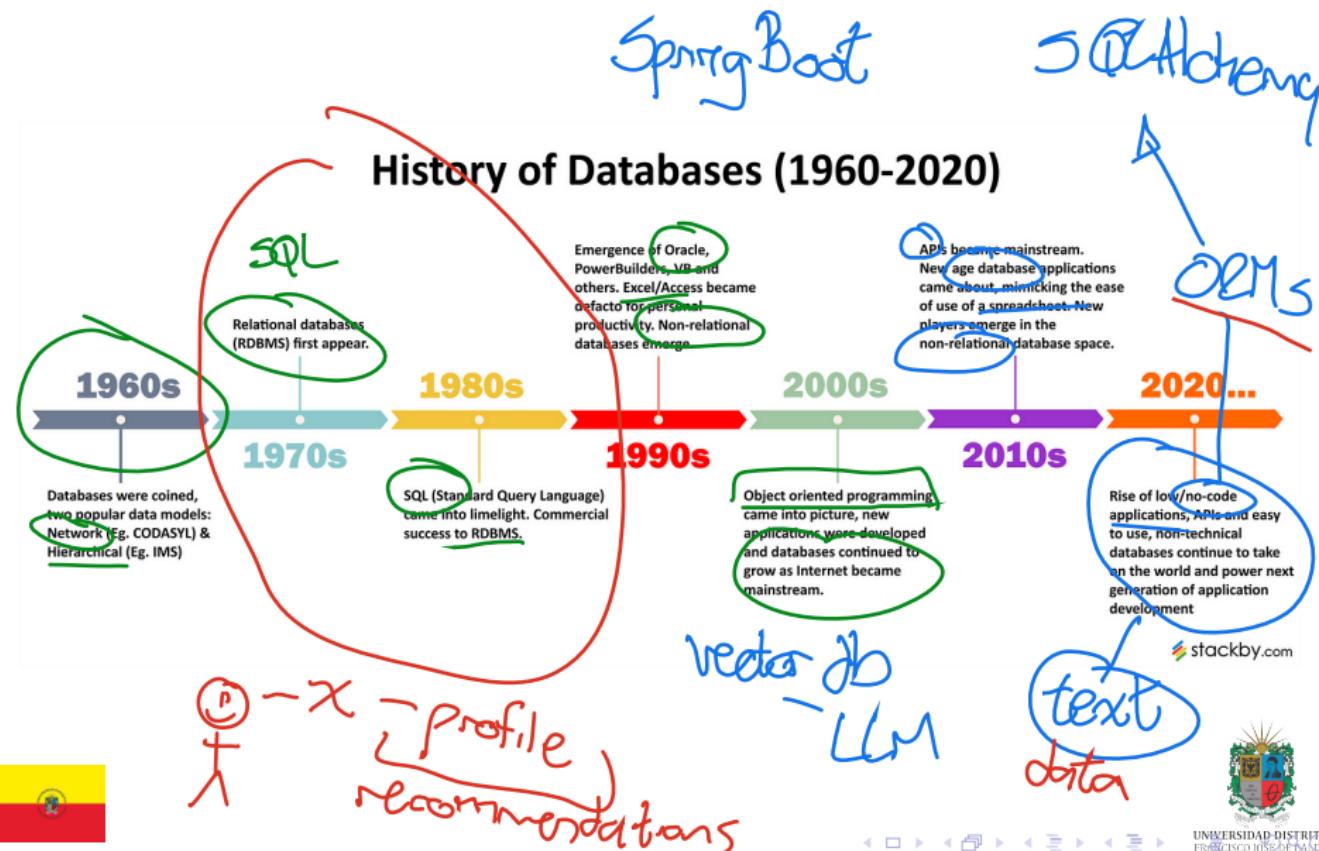
source

11

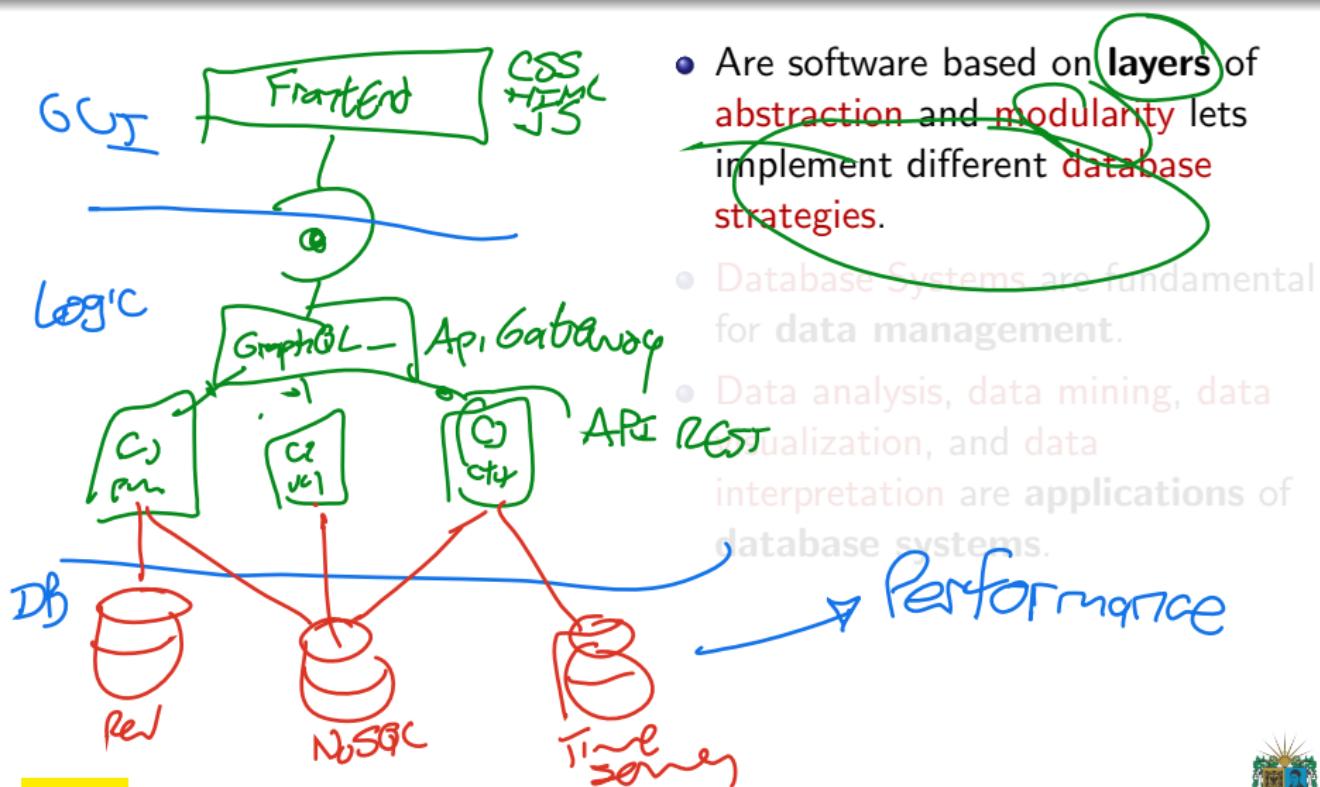
 Ethic \rightarrow LCM
GPS, speed, weight.



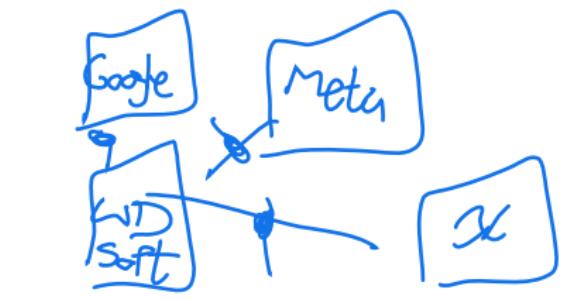
History of DataBases



Applications



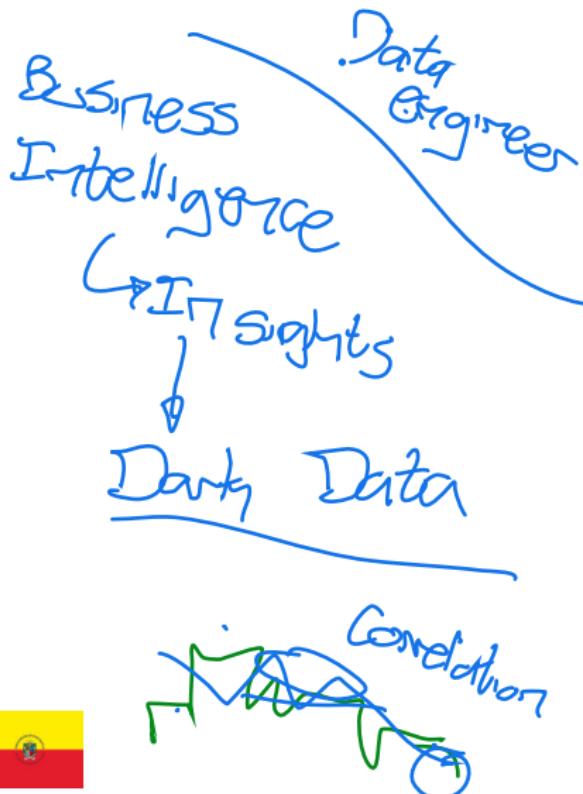
Applications



- Are software based on **layers of abstraction** and **modularity** lets implement different **database strategies**.
- **Database Systems** are fundamental for **data management**.



Applications

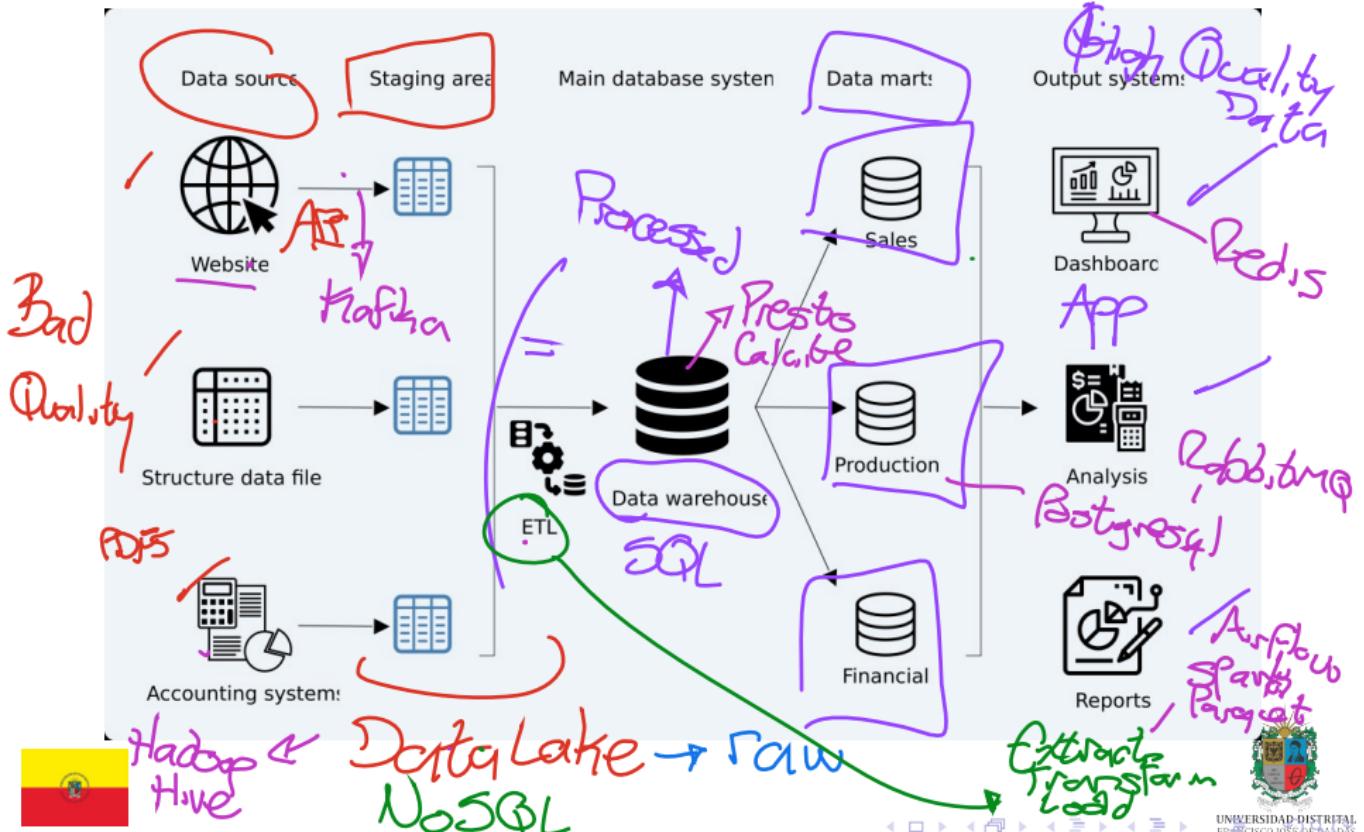


- Are software based on **layers of abstraction** and **modularity** lets implement different **database strategies**.
- Database Systems are fundamental for **data management**
- **Data analysis, data mining, data visualization, and data interpretation** are **applications** of **database systems**.

Dashboard

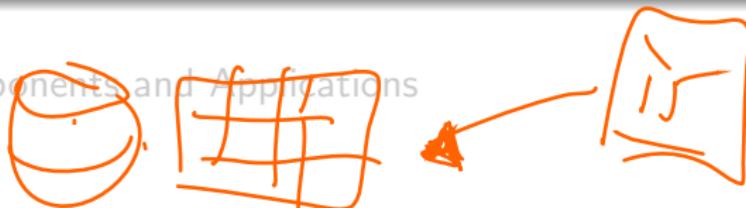


Case of Study: DataBase System



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1 Software Components and Applications



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4 Relational DataBase Design

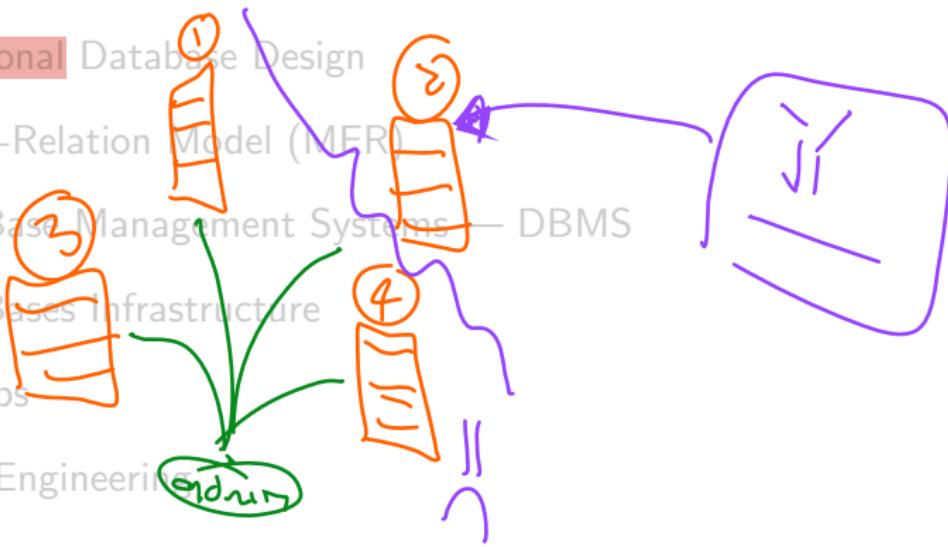
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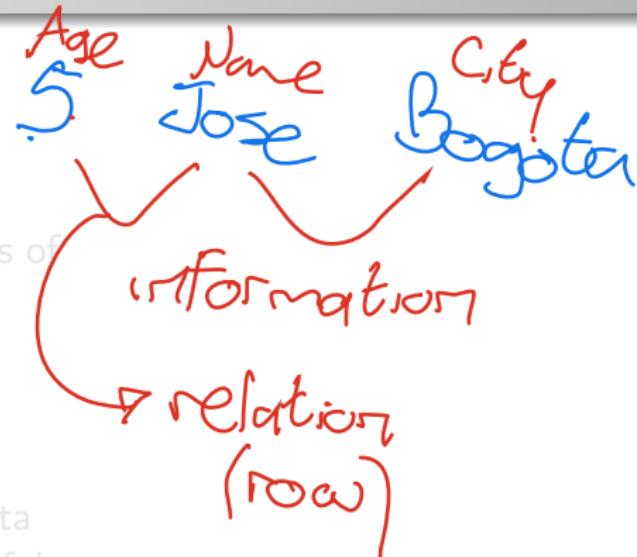
8 DevOps

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From Data to Information

- **Data:** is a set of values of **qualitative** or **quantitative** variables.
- **Data Management:** is the process of collecting, storing, processing, and analyzing data.
- **numbers**
- **numbers**
- **categories**
- **category**



From Data to Information

- **Data:** is a set of **values** of **qualitative** or **quantitative** variables.
- **Data Management:** is the process of **collecting**, **storing**, **processing**, and **analyzing** data.

Sources

→ **formats**

→ **quality**

→ **ELT**

→ **ELT(L)**

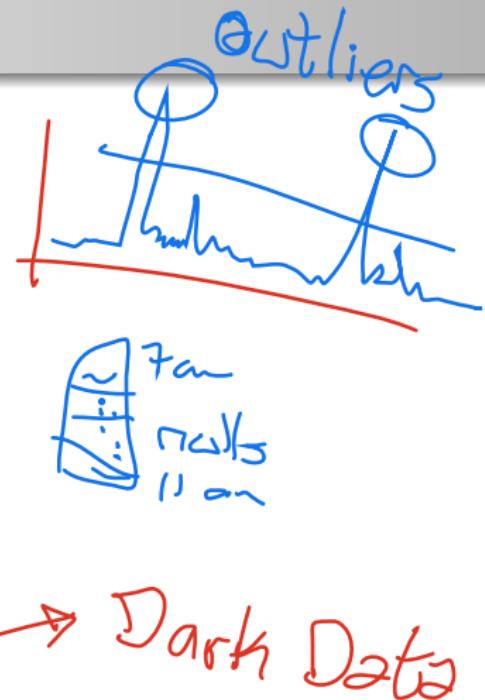
→ **offline**

→ **online**



From Data to Information

- **Data:** is a set of **values** of **qualitative** or **quantitative** variables.
- **Data Management:** is the process of **collecting**, **storing**, **processing**, and **analyzing** data.
- **Data Analysis:** is a process of **inspecting**, **cleaning**, **transforming**, and **modeling** data with the goal of **discovering** useful **information**, informing **conclusions**, and supporting **decision-making**.



Structured and Unstructured Data

Power BI  table

WAN - Web - colores

Structured Data

vs

Unstructured Data

Name 

Can be displayed
in rows, columns and
relational databases



Numbers, dates
and strings

Estimated 20% of
enterprise data (Gartner)

20%

Requires less storage



Easier to manage
and protect with
legacy solutions



natives

relationship

redundancy



Cannot be displayed
in rows, columns and
relational databases



Images, audio, video,
word processing files,
e-mails, spreadsheets



Estimated 80% of
enterprise data (Gartner)



Requires more storage

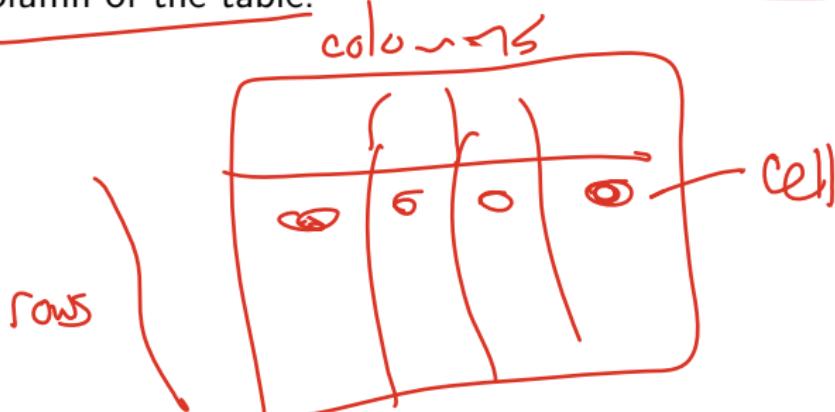


More difficult to
manage and protect
with legacy solutions



Tables, Columns and Rows

- **Table** is a collection of related data held in a structured format within a database.
- **Column** is a set of data values of a particular simple type, one for each row of the table.
- **Row** is a set of data values of a particular relationship, one for each column of the table.



Primary and Foreign Keys

- Primary Key is a unique identifier for a record in a data set.
- Foreign Key is a column or group of columns in a table that links to a primary key in another table.

Country

code	name
S7	Colombia
S9	Argentina

PK



code	City	Country
1	Bogotá	S7
2	Buenos	S9
3	Cordoba	S9
4	Mérida	S7
5	Salta	S9
6	Patagonia	S9



Key-Value Data Structures

No redundancy → 90s

- **Key-Value Data Structures** are a type of data structure that can map keys to values.
- **Key** is a unique identifier for a record in a data fragment. **Value** is the data that is associated with the key.



CRUD Operations

- **CRUD** is an acronym for **Create, Read, Update, and Delete**.
- **Create** is the process of **adding new records** to a **data set**.
- **Read** is the process of **retrieving records** from a **data set**.
- **Update** is the process of **modifying records** in a **data set**.
- **Delete** is the process of **removing records** from a **data set**.

4 operations
for all apps

Law of Demand



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 Domain-Driven Design

~~Entity-Relationship Model~~

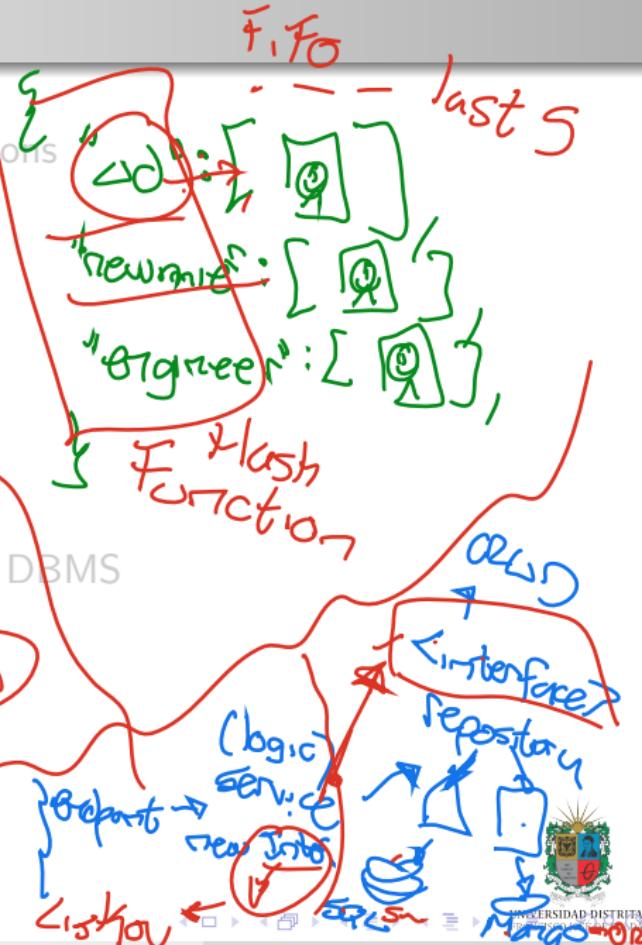
~~Relational Database~~

~~DataBase Classification~~

~~DataBases Infrastructure~~

~~DevOps~~

~~Data Engineering~~



DataBase Classification

- DataBase is a collection of data that is organized so that it can be easily accessed, managed, and updated.
- Relational DataBase is a type of database that stores and provides access to data points that are related to one another.
- NoSQL DataBase is a type of database that provides a mechanism for storage and retrieval of data that is modeled in means other than the tabular relations used in relational databases.



DataBase Classification

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E~SNS

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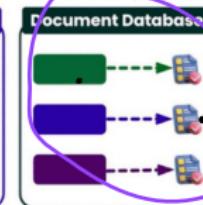
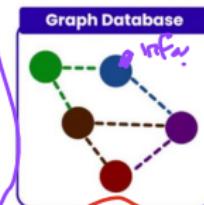
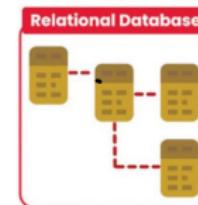
Types of Database

TEST → PC

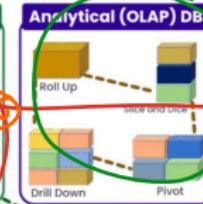
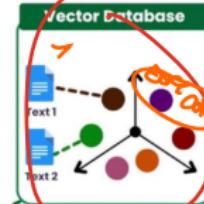
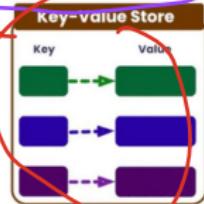


JSON → BSON

How Many Types of Database Do You Know?



١٥٢



Overlap

6

OLAP

```

class {
    int id;
    String name;
    String password;
}

```

The diagram illustrates a class structure. It starts with the keyword 'class' followed by a brace. Inside the brace, there are three attribute declarations: 'int id;', 'String name;', and 'String password;'. Each attribute is preceded by its type and name, separated by a semicolon.



DataBases Models



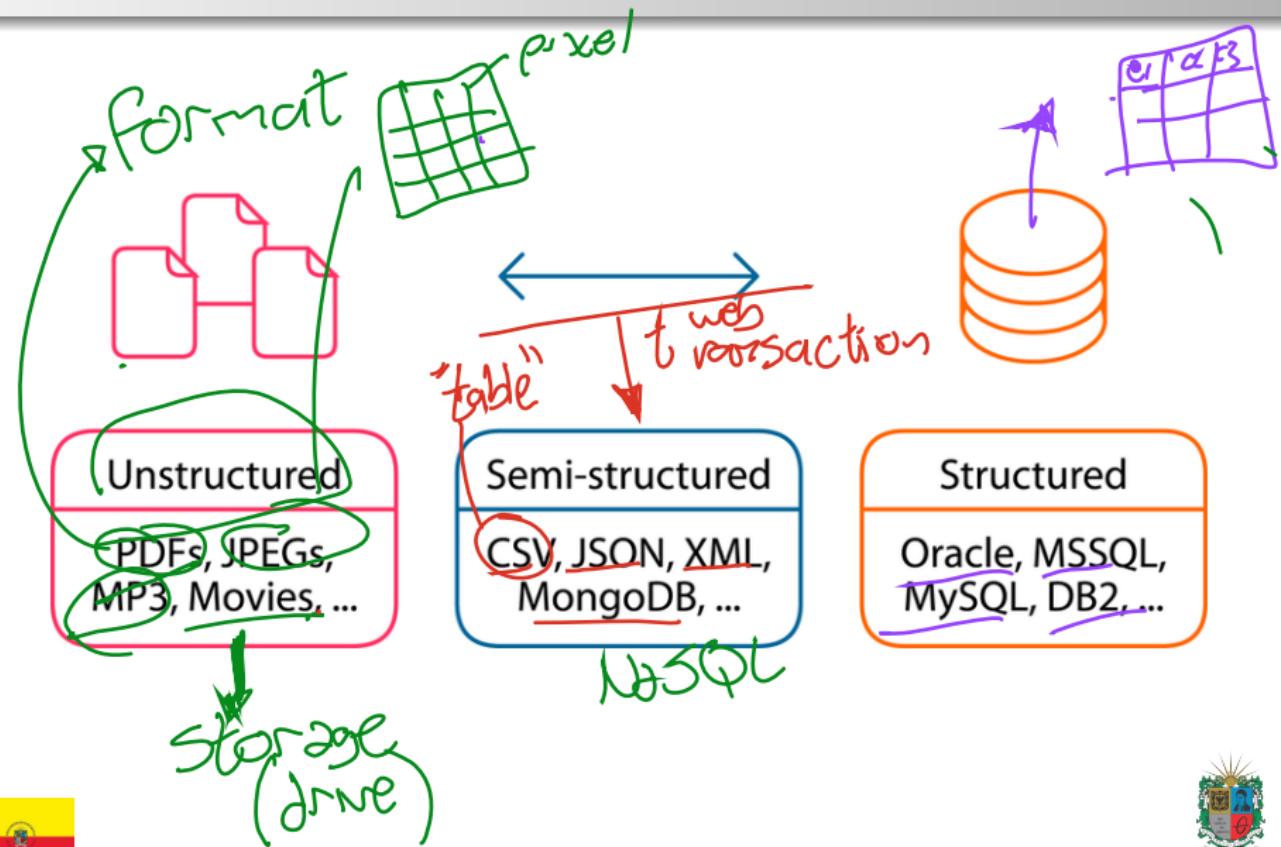
DataBases Models are the way to organize and store data in a database.

There are some common models:

- Hierarchical
- Network
- Relational
- Object-Oriented
- Document-Based
- Graph-Based
- ... ?



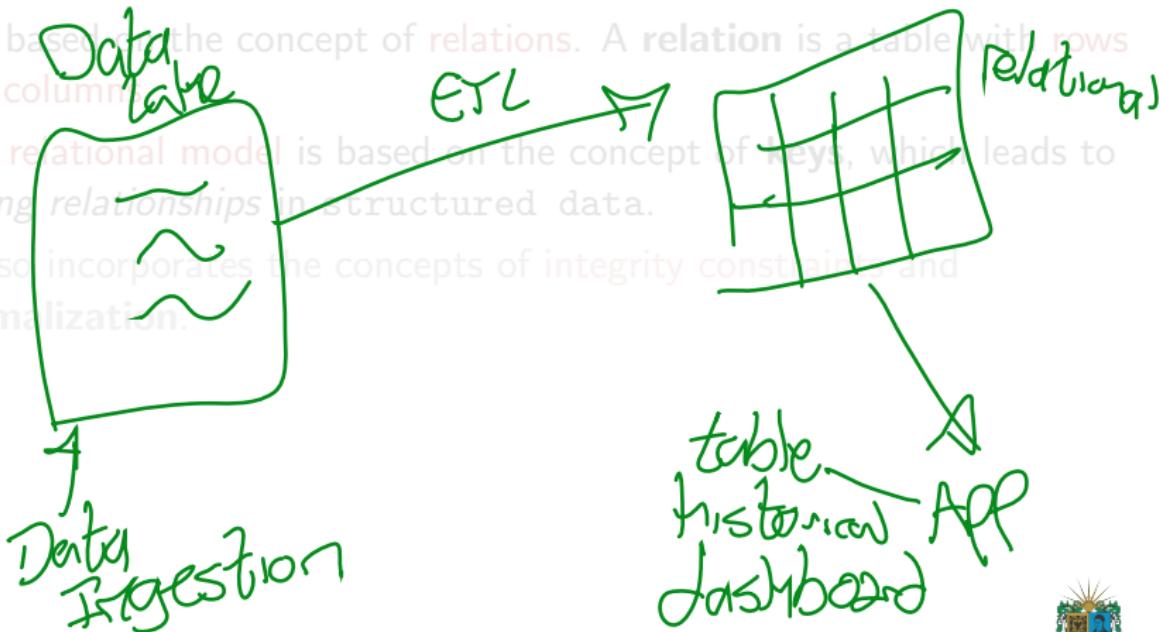
Semi-Structured Data



Relational Model

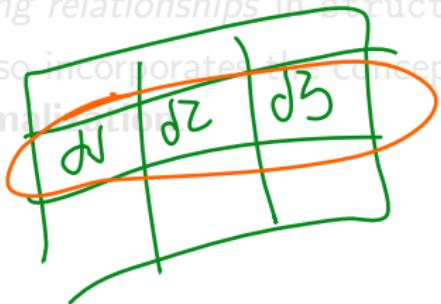
- The **relational model** is the **most common** and widely used model today.

- It is based on the concept of **relations**. A relation is a table with **rows** and **columns**.
- The relational model is based on the concept of **keys**, which leads to **strong relationships** in structured data.
- It also incorporates the concepts of **integrity constraints** and **normalization**.



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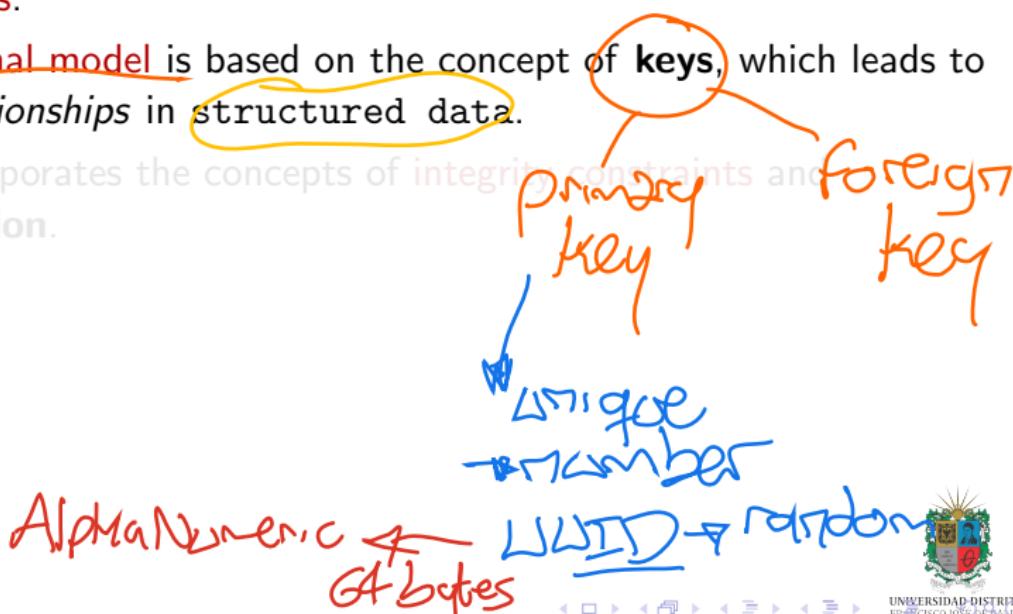


relation



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→ FN
↓
↓ FN

→ standardize

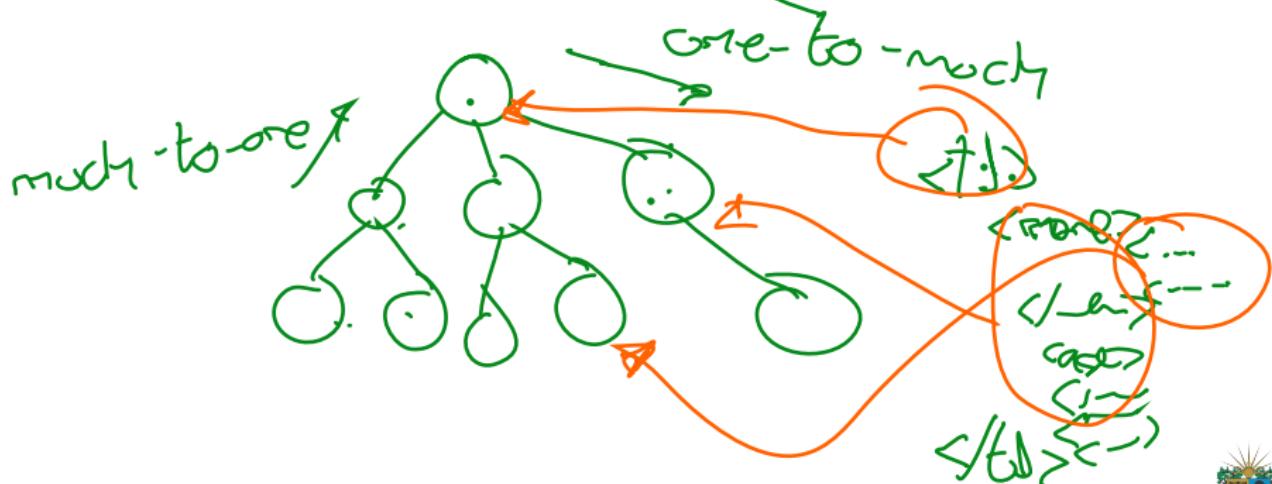
→ ↗ no redundancy

→ ↗ no m-m relations

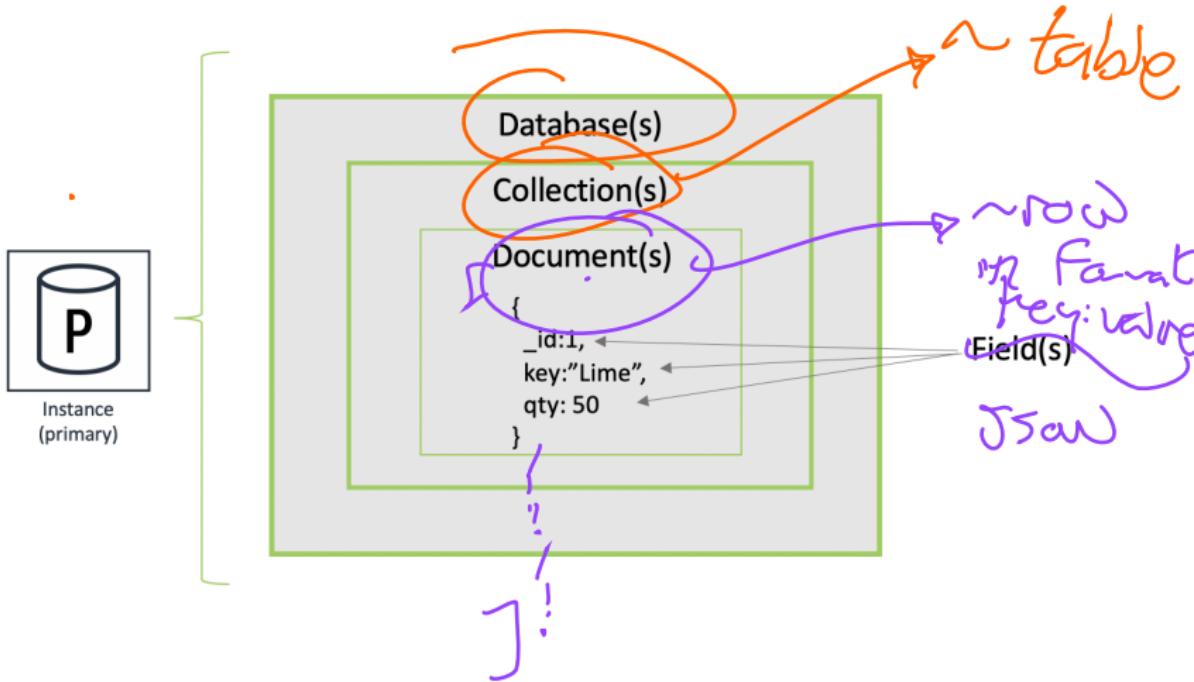


Hierarchical Model

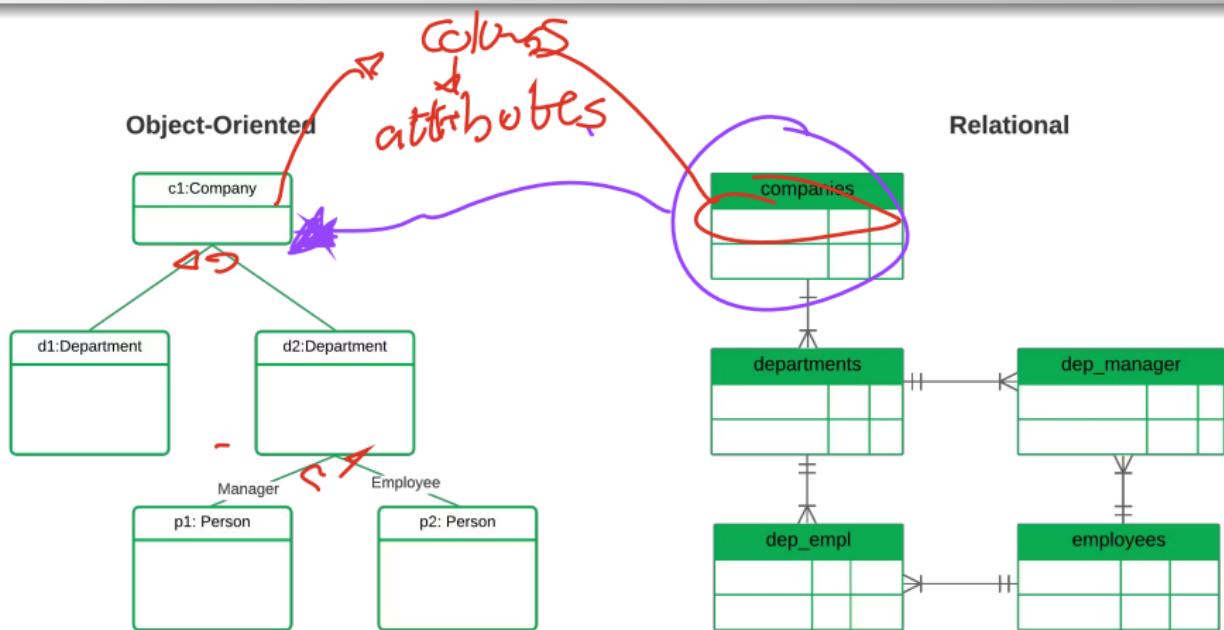
- The **hierarchical model** organizes data in a **tree-like structure**.
 - It is based on the concept of **parent-child relationships**, meaning **one-to-many** relationships.
 - An example of a **hierarchical model** is the **XML format**.



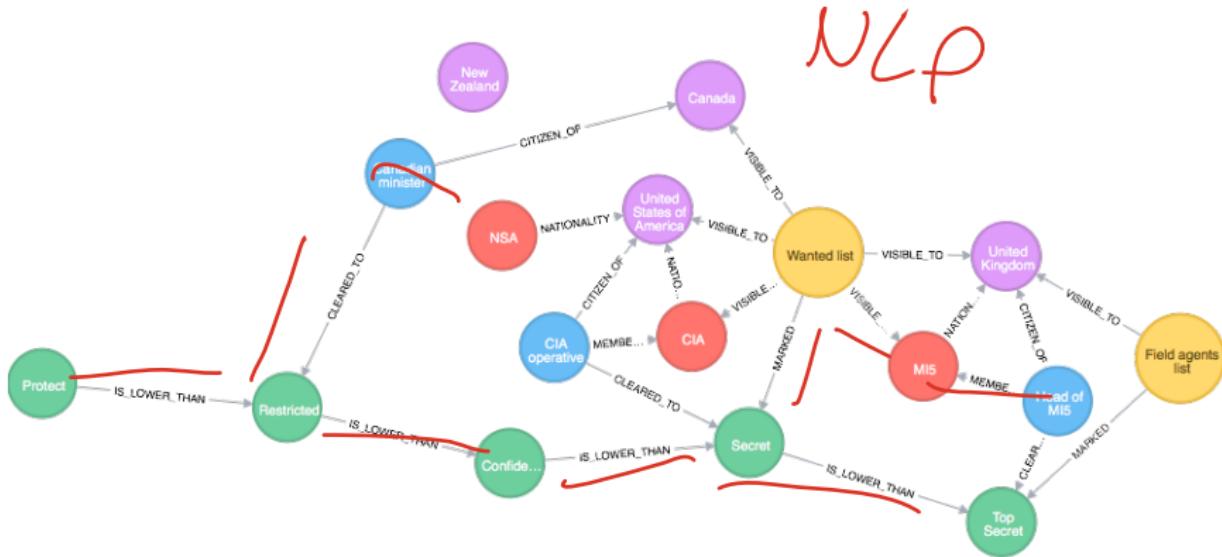
Document-Based Model



Object-Oriented Model



Graph-Based Model



NoSQL Model

What is NoSQL Database



educba.com



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Database Design Foundations

- In the context of **databases**, **designing** a database is the process of producing a **detailed data model**.
- This **data model** encompasses all the required **logical and physical design decisions**, as well as **physical storage parameters**, to generate a design in a *data definition language* that can subsequently be used to create the database.
- A **fully attributed data model** contains detailed attributes for **each entity**.
- Relational data models avoid redundancy and inconsistency by ensuring that data is **normalized**.



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Set Theory in Databases

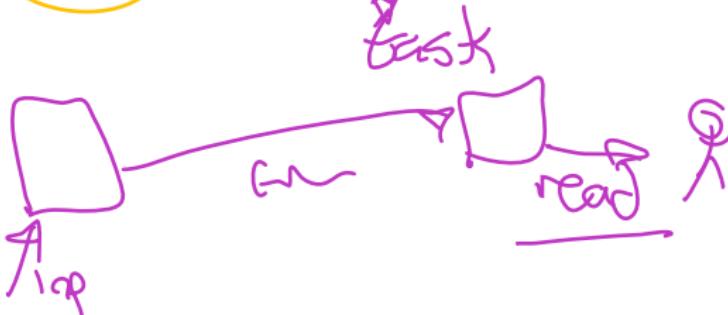
- The set theory is a branch of mathematical logic that studies sets, which are collections of objects.
- The set theory is applied in databases to define the relational model and the relational algebra.
- The relational model is a mathematical model of data for large shared data banks and it has a solid theoretical foundation.
- The relational algebra is a procedural query language, which takes relations as input and produces relations as output.



Set Theory in Databases



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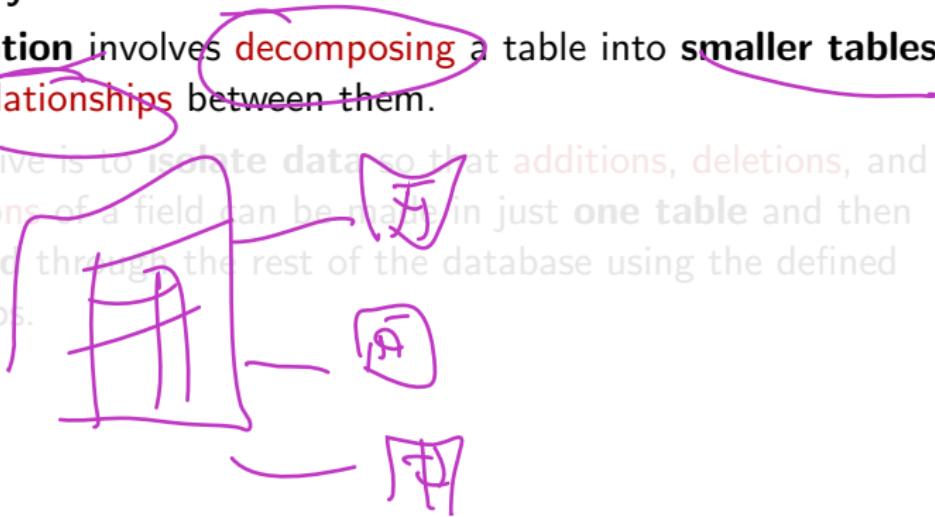
Normalization in Databases

- **Normalization** is the process of **organizing** the **columns** (attributes) and **tables** (relations) of a relational database to **minimize data redundancy**.
- Normalization involves decomposing a table into smaller **tables** and defining **relationships** between them.
- The objective is to **isolate data** so that **additions**, **deletions**, and **modifications** of a field can be made in just **one table** and then **propagated** through the rest of the database using the defined relationships.



Normalization in Databases

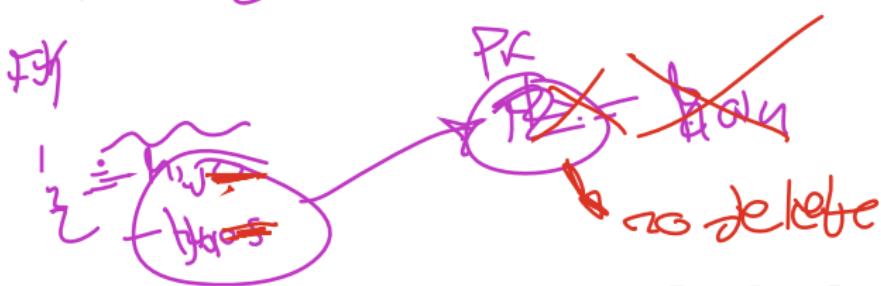
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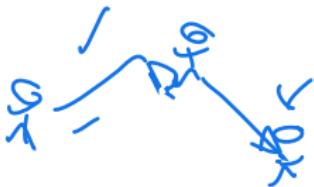
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→ Cascade



Normal Levels

- ① **First normal form (1NF)**: The table is a two-dimensional table with rows and columns. Each column contains atomic values, and there are no repeating groups or arrays.
- ② **Second normal form (2NF)**: The table is in first normal form and all the non-key attributes are fully functionally dependent on the primary key.
- ③ **Third normal form (3NF)**: The table is in second normal form and all the non-key attributes are non-transitively dependent on the primary key.
- ④ **Fourth normal form (4NF)**: The table is in third normal form and there are no multi-valued dependencies.



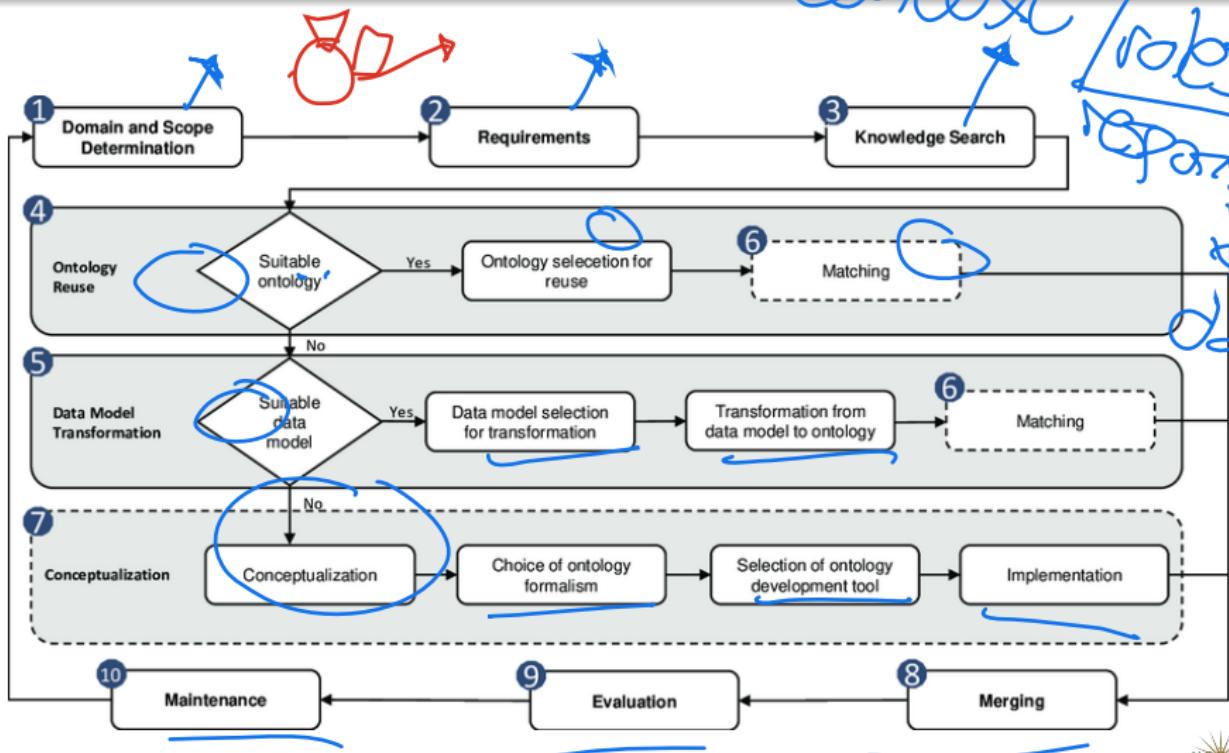
Ontologies

web semantics

- An **ontology** is a formal naming and definition of the types, properties, and interrelationships of the entities that really or fundamentally exist for a particular domain of discourse.
- **Ontologies** are used in databases to define the schema of the database.
- The **schema** of a database is a formal definition of the structure of the database: the types of data that are stored, the relationships between the data, and the constraints on the data.



Ontology Workflow



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Definitions

- **Entity:** A thing or object in the real world that is distinguishable from other objects.
- **Attribute:** A property or characteristic of an entity.
- **Relationship:** An association between entities.
- **Cardinality:** The number of instances of an entity that can be associated with another entity.
- **Degree:** The number of entities that participate in a relationship.



List
of
rows



col
List
of
objects



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4 Data type
constraints

source → API \$

web scraping
errors... low quality

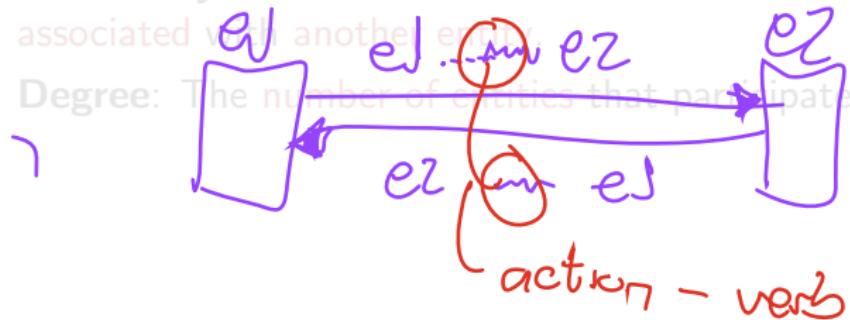
HTML → tags

metatag → JSON



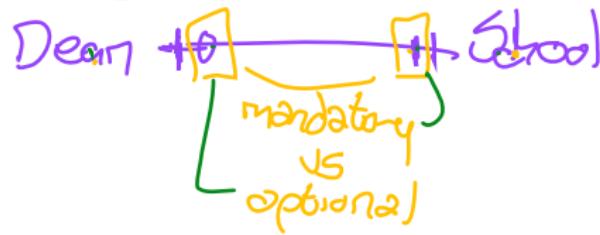
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Definitions

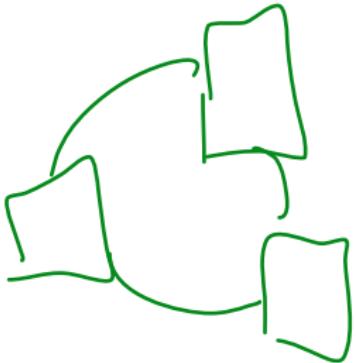
- **Entity:** A thing or object in the real world that is **distinguishable** from other **objects**.
- **Attribute:** A **property** or characteristic of an **entity**.
- **Relationship:** An **association** between entities.
- **Cardinality:** The number of **instances** of an **entity** that can be **associated** with another entity.
- **Degree:** The number of entities that participate in a relationship.



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Entity-Relation Model

- The **Entity-Relation Model** is a graphical representation of the **entities** and their **relationships** in a **database**.
- The Entity-Relation Model is used to design the schema of a database and to communicate the design to stakeholders.
- Following a process based on a **ontology** it is easy to define the entities, attributes, and relationships of the database.



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Database

↳ Schemas

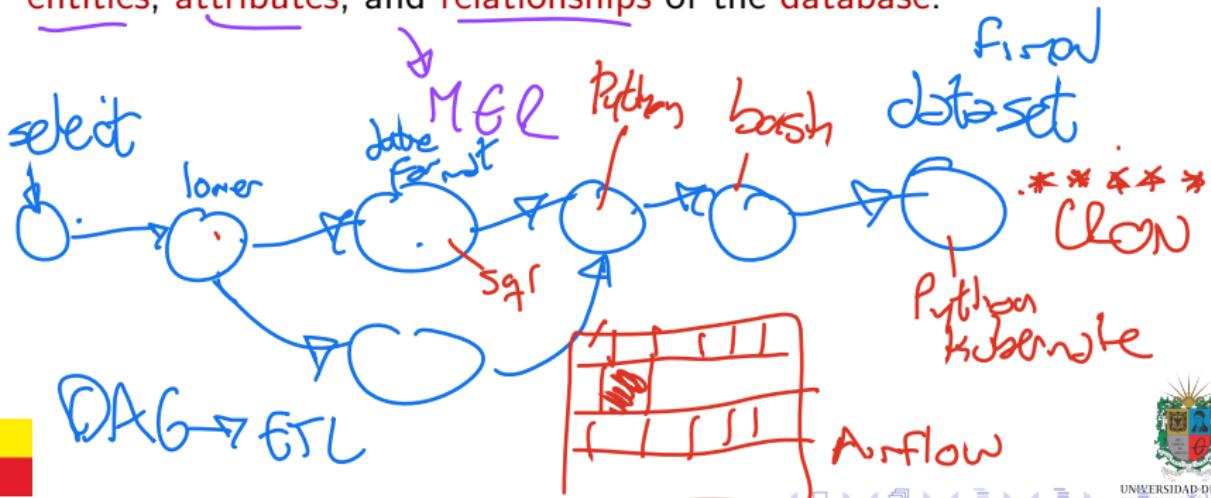
↳ Tables

↳ Rows

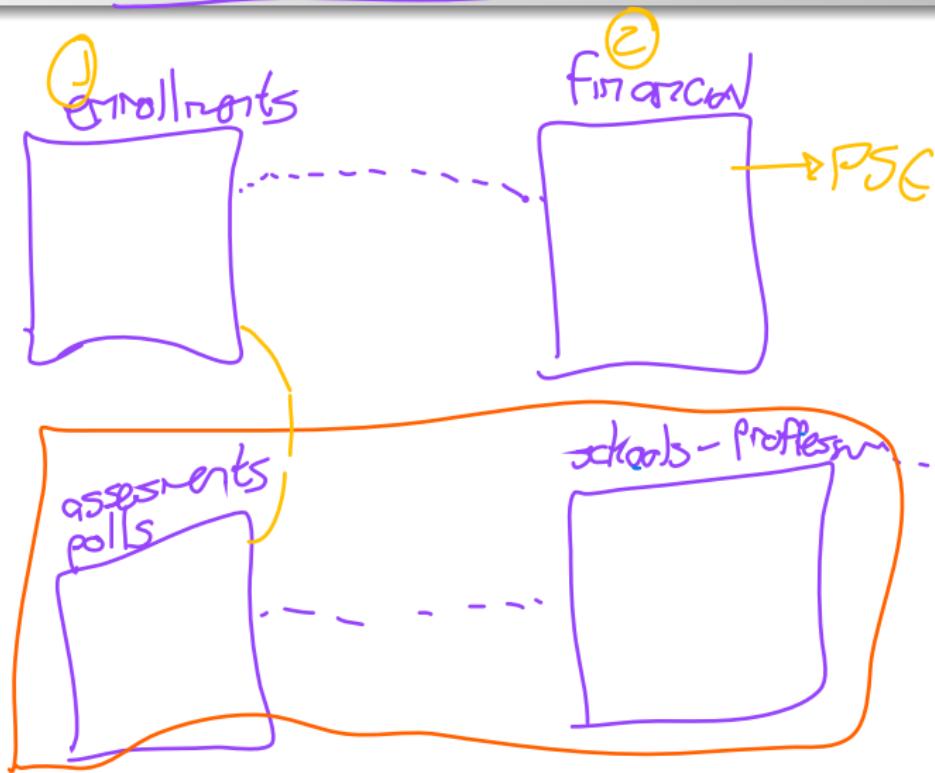


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Step 1. Define Components



Step 2. Define Entities



e- student

et Professor

FINANCIAC

c7. Payment

ets-Bark

e-Services

Don ell - Payment Method

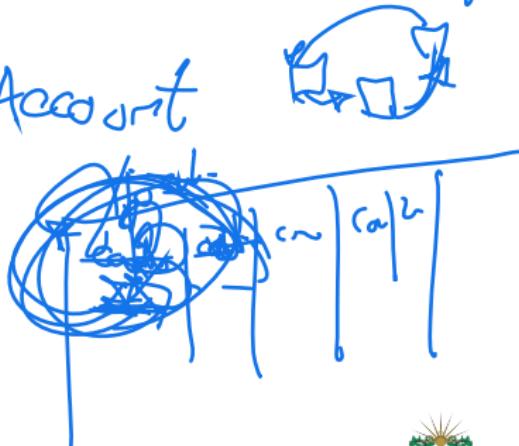
e3Group

eb-Groß

1

e12-CourseType

e14. Location type



domain $\begin{cases} \text{no charge} \\ \text{simple} \end{cases}$ } 1) same description

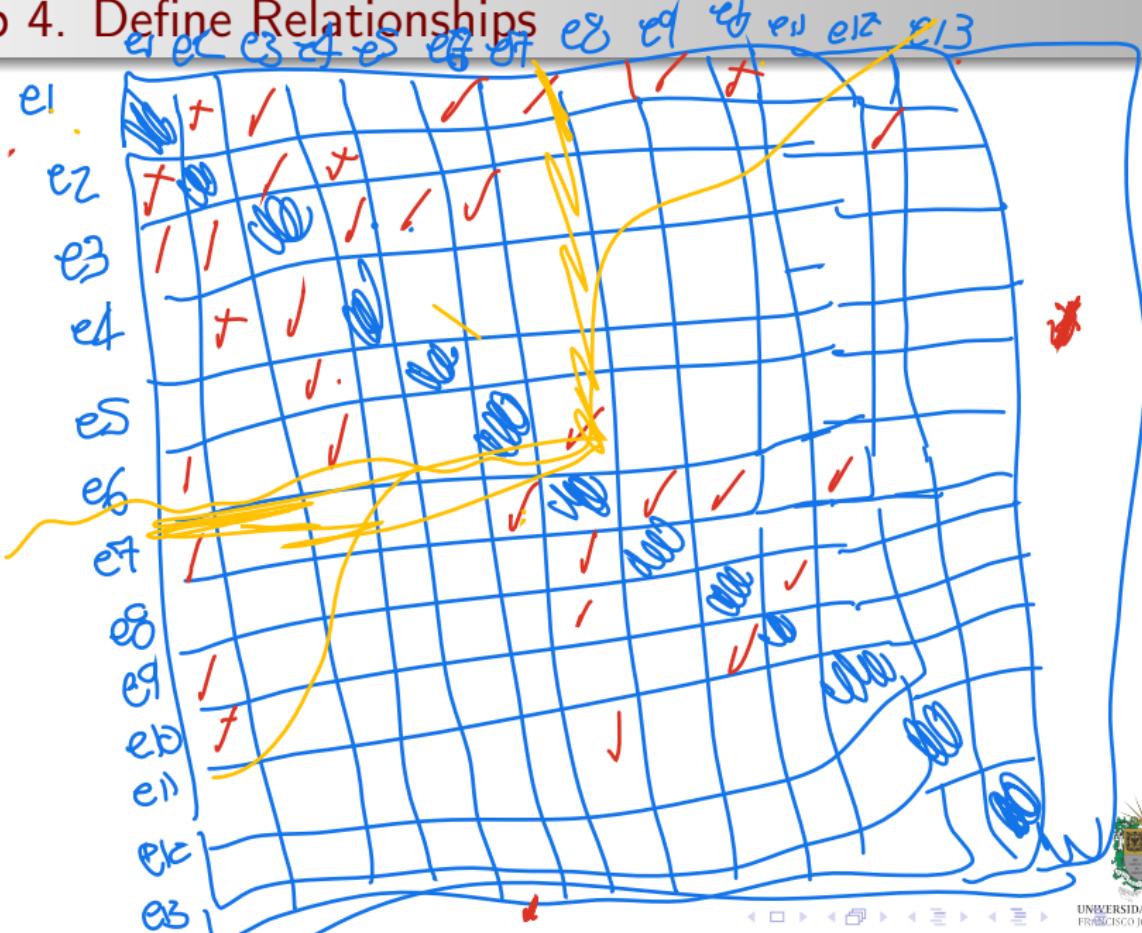


Step 3. Define Attributes per Entity

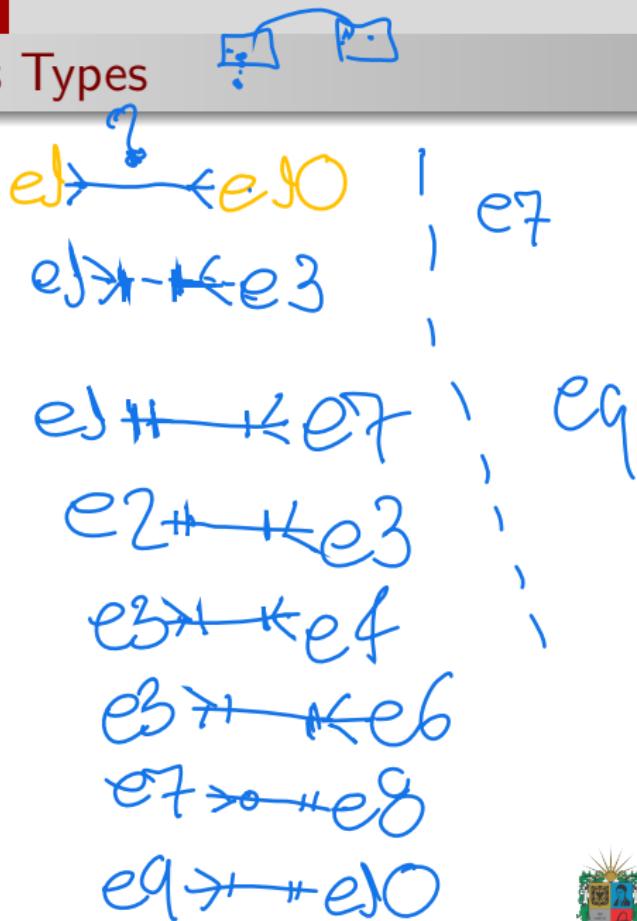
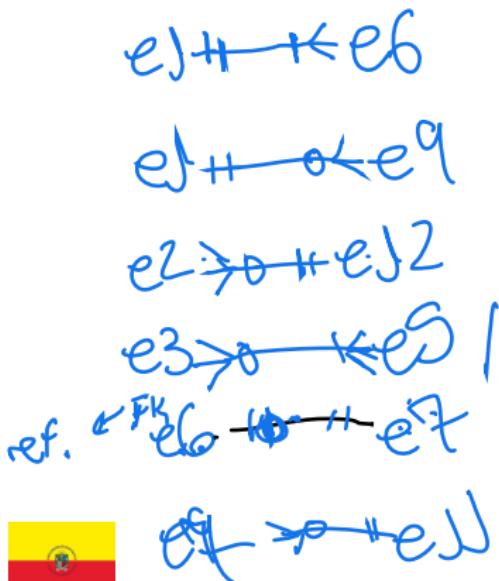
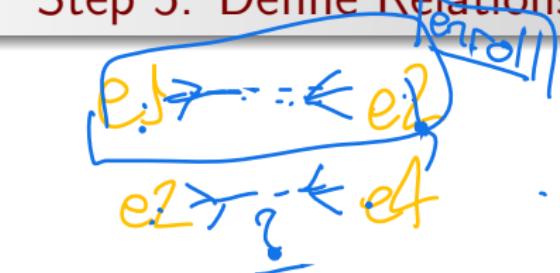
- e1. name, address, email, phone, birthday, national-id
- e2. name, credit, description, code, type
- e3. code, name, course, rooms, max-students, schedule
- e4. code, email, name, max-degree, phone
- e5. building, name, description, lat-long, type, max-occupancy
- e6. student, group, registration-date, session
- e7. value, tax, due-date, student, service, payment-method, observations, successful
- e8. name, cost, description,
- e9. name, type, number, bank, debt
- e10. Name, country, NIT
- e11. id, name, description, rate
- e12. id, name, description
- e13. id, name, description



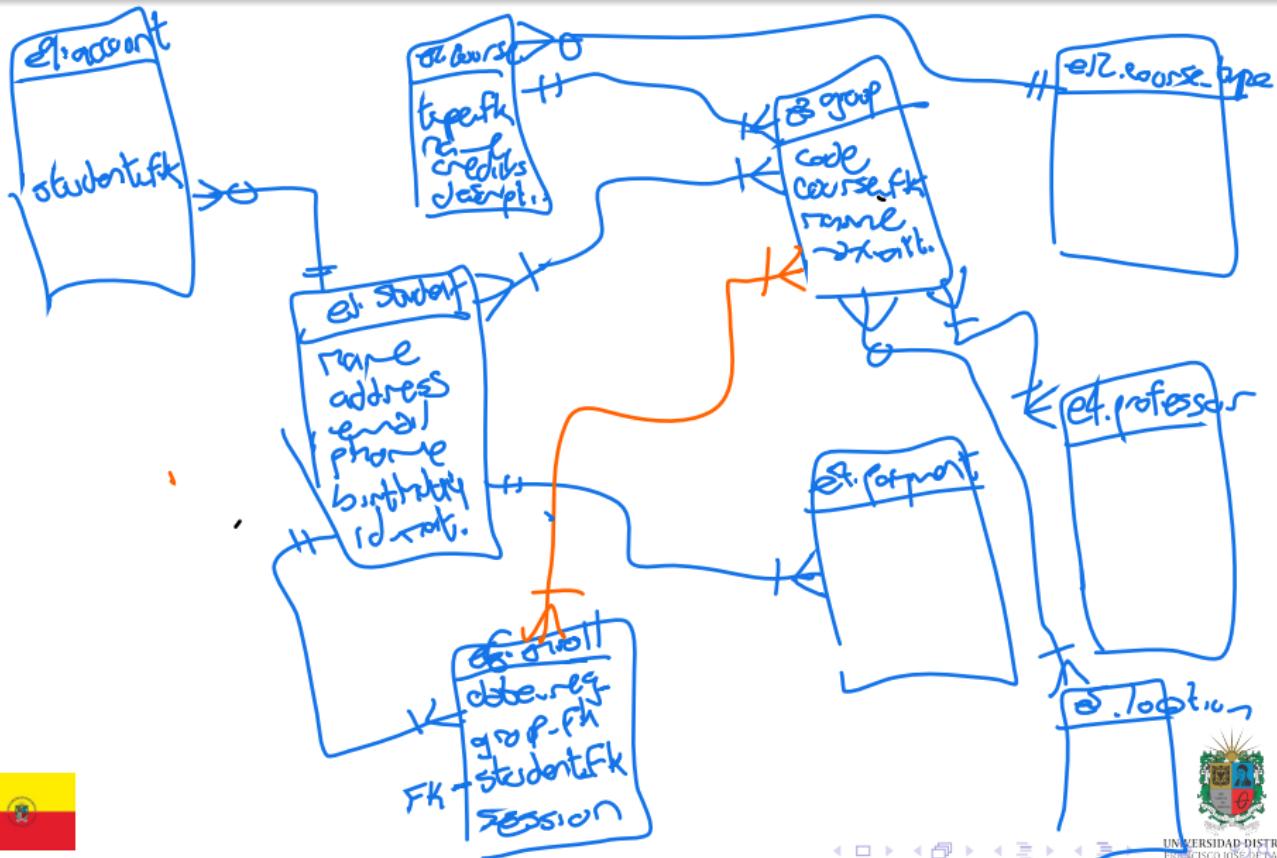
Step 4. Define Relationships



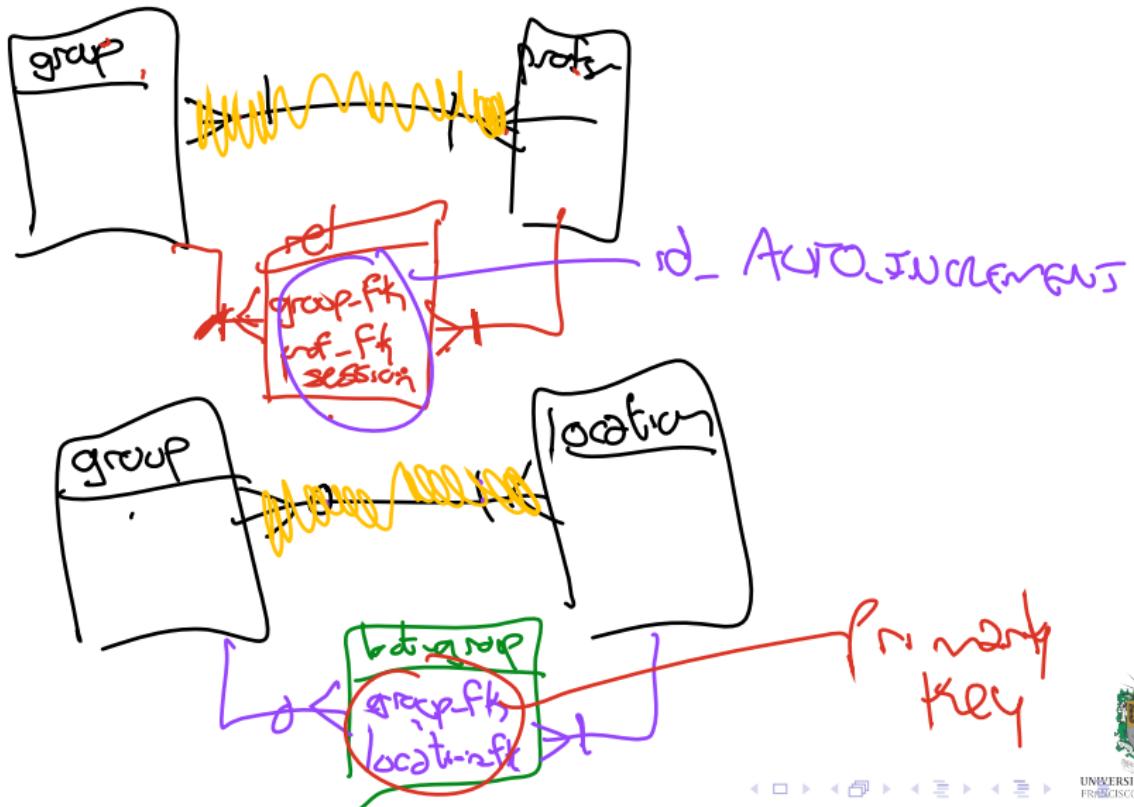
Step 5. Define Relationships Types



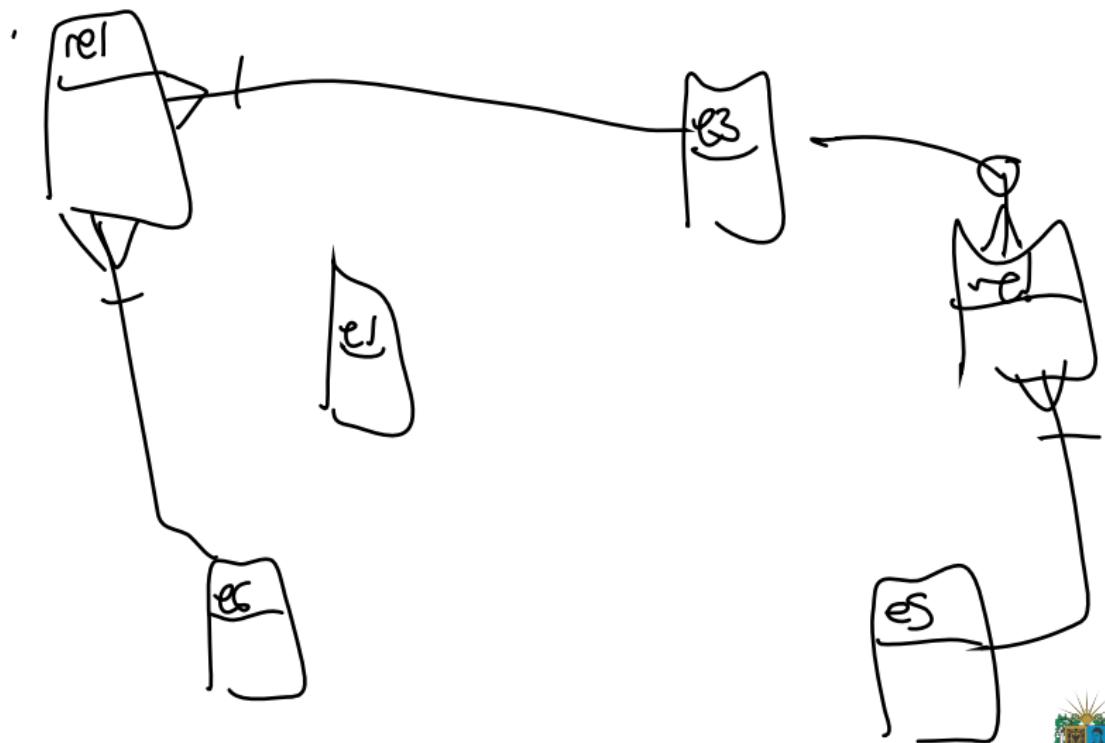
Step 6. First Entity-Relationship Model Draw



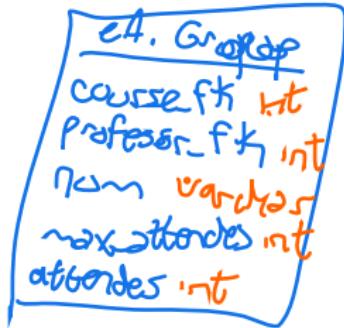
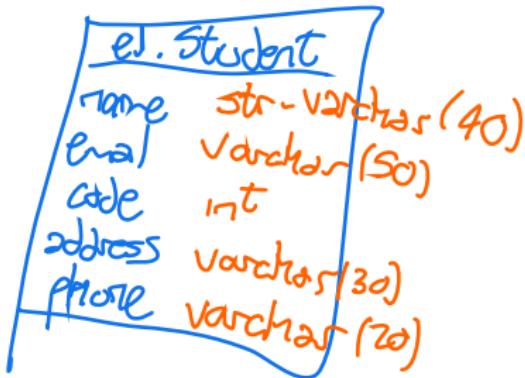
Step 7. Split Many-to-Many Relationships



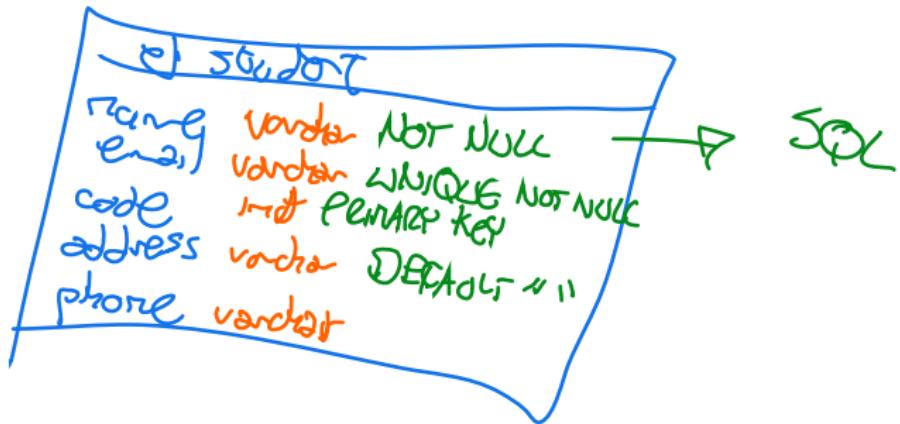
Step 8. Second Entity-Relationship Model Draw



Step 9. Get Data-Structure Entity-Relationship Model



Step 10. Define Constraints and Properties of Data



```
CREATE TABLE IF NOT EXISTS student(
    name VARCHAR(40) NOT NULL,
    email VARCHAR(50) UNIQUE NOT NULL,
    code INT PRIMARY KEY,
    address VARCHAR(50) DEFAULT '',
    phone VARCHAR(30)
)
```



Outline

- 1 Software Components and Applications
- 2 Glosary
- 3 DataBase Classification
- 4 Relational Database Design
- 5 Entity-Relation Model (MER)
- 6 DataBase Management Systems — DBMS
- 7 DataBases Infrastructure
- 8 DevOps
- 9 Data Engineering



What is a DBMS?

- A **Database Management System (DBMS)** is a **software system** that uses a **standard** method to **store** and **organize** data.
- A **DBMS** is a **software system** that allows users to define, create, maintain, and control access to the database.
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transformations

integrity

Grants
Security



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\hookrightarrow SQL \Rightarrow Declarative



Pros & Cons of DBMS

• Pros:

- **Data Independence:** Data is stored independently of the applications that use it.
- **Data Integrity:** Data is consistent and accurate.
- **Data Security:** Data is protected from unauthorized access.
- **Data Recovery:** Data can be recovered in case of failure.

• Cons:

- Complexity: DBMS are complex systems.
- Cost: DBMS are expensive for bigger data volumes.
- Performance: DBMS can be slow.



Pros & Cons of DBMS

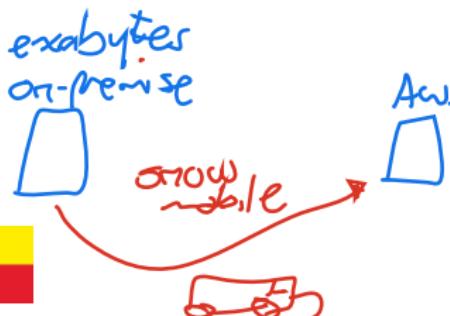
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maintain



GUI Assistants

- A **Graphical User Interface (GUI)** is a type of user interface that allows users to **interact** with electronic devices using **graphical icons** and **visual indicators**.
- GUIs are **easier** to use than Command Line Interfaces (**CLI**) because they allow users to **interact** with the system using **visual elements** such as **windows**, **buttons**, and **menus**.
- GUIs are more **intuitive** and **user-friendly** than CLIs, which makes them ideal for **users** who are **not familiar** with the system.

MySQL \Rightarrow WorkBench

Postgres \Rightarrow PgAdmin



Case of Study: DBeaver

Agnostic

The screenshot shows the DBeaver 22.1.3 interface with the following details:

- Database Navigator:** Shows the database structure. Under the 'system' database, there is a 'mover' schema containing tables like 'crdb_internal', 'public', 'rides', 'user_promo_codes', 'users', 'vehicle_location_histories', and 'vehicles'. There are also 'Views', 'Indexes', 'Functions', 'Sequences', and system info.
- Project - General:** Shows a project named 'DataSource' with items: Bookmarks, ER Diagrams, and Scripts.
- Properties View:** For the 'rides' table (Object ID: 111, Owner: root).

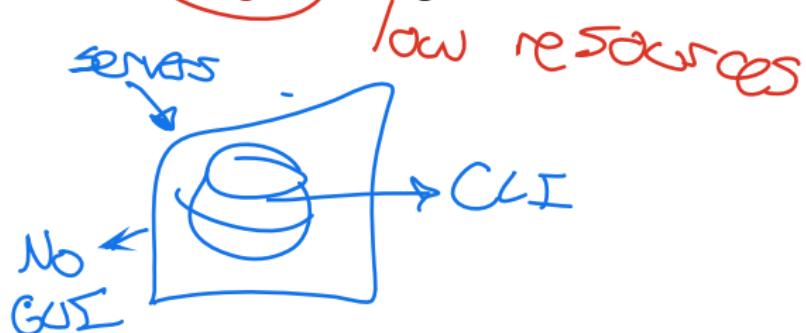
Column Name	#	Data type	Identity	Collation	Not Null	Default	Comments
id	1	uuid			[v]		
city	2	varchar	default		[v]		
vehicle_city	3	varchar	default				
rider_id	4	uuid					
vehicle_id	5	uuid					
start_address	6	varchar	default				
end_address	7	varchar	default				
start_time	8	timestamp					
end_time	9	timestamp					
revenue	10	numeric(10, 2)					



Command Line

Command Prompt Terminal

- A **Command Line Interface** (CLI) is a type of user interface that allows users to interact with electronic devices using text-based commands.
- CLIs are more powerful and flexible than GUIs because they allow users to perform complex tasks using simple commands.
- CLIs are more efficient than GUIs because they do not require users to navigate through menus and windows to perform tasks.



Case of Study: MariaDB CLI

```
arnel@arnel.com [~]# mysql -u arnel_test2 -p
Enter password:
Welcome to the MariaDB monitor.  Commands end with ; or \g.
Your MariaDB connection id is 8643
Server version: 10.1.25-MariaDB MariaDB Server

Copyright (c) 2000, 2017, Oracle, MariaDB Corporation Ab and others.

Type 'help;' or '\h' for help. Type '\c' to clear the current input statement.

MariaDB [(none)]> show databases;
+-----+
| Database      |
+-----+
| arnel_test1   |
| arnel_test2   |
| information_schema |
+-----+
3 rows in set (0.00 sec)

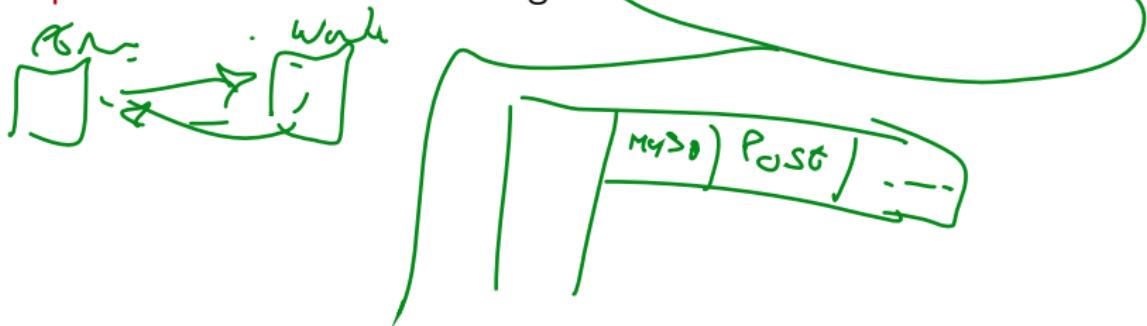
MariaDB [(none)]> use arnel_test1
Reading table information for completion of table and column names
You can turn off this feature to get a quicker startup with -A

Database changed
MariaDB [arnel_test1]>
```



Why use an agnostic tool?

- An **agnostic tool** is a tool that is **not tied** to a specific technology or platform.
- **Agnostic tools** are useful because they allow users to work with multiple databases without having to learn different tools.
- **Agnostic tools** are also useful because they allow users to work with multiple databases without having to switch between different tools.



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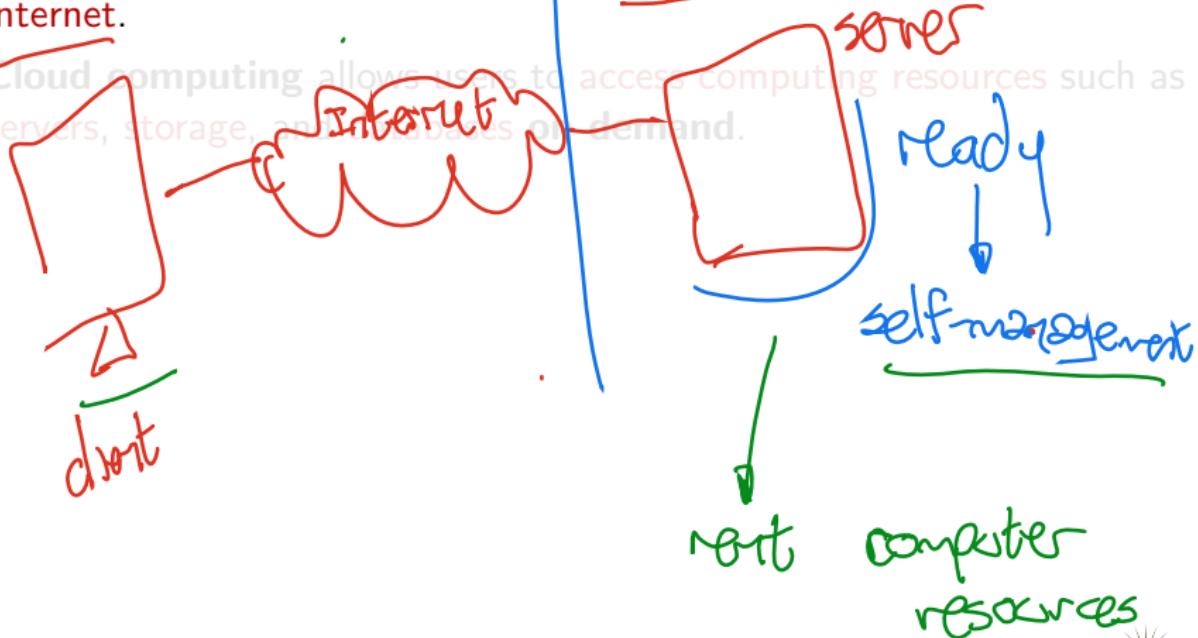
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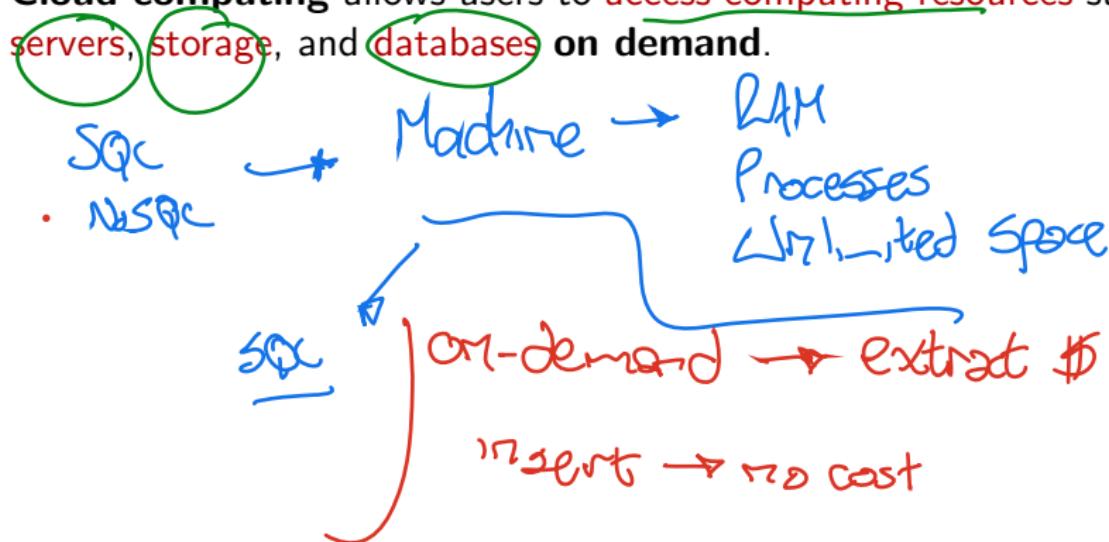
What is the Cloud Computing?

- **Cloud computing** is the delivery of computing services over the internet.
- Cloud computing allows users to access computing resources such as servers, storage, and databases on demand.



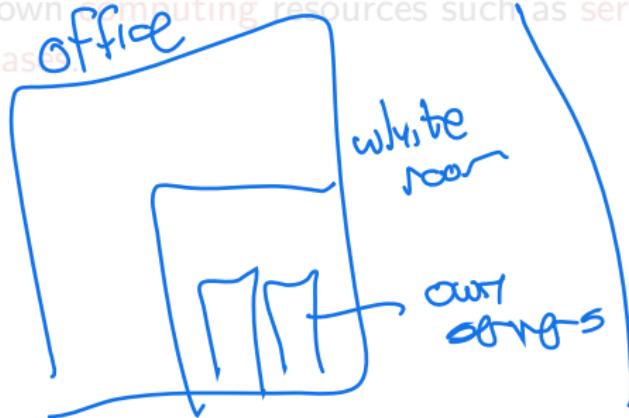
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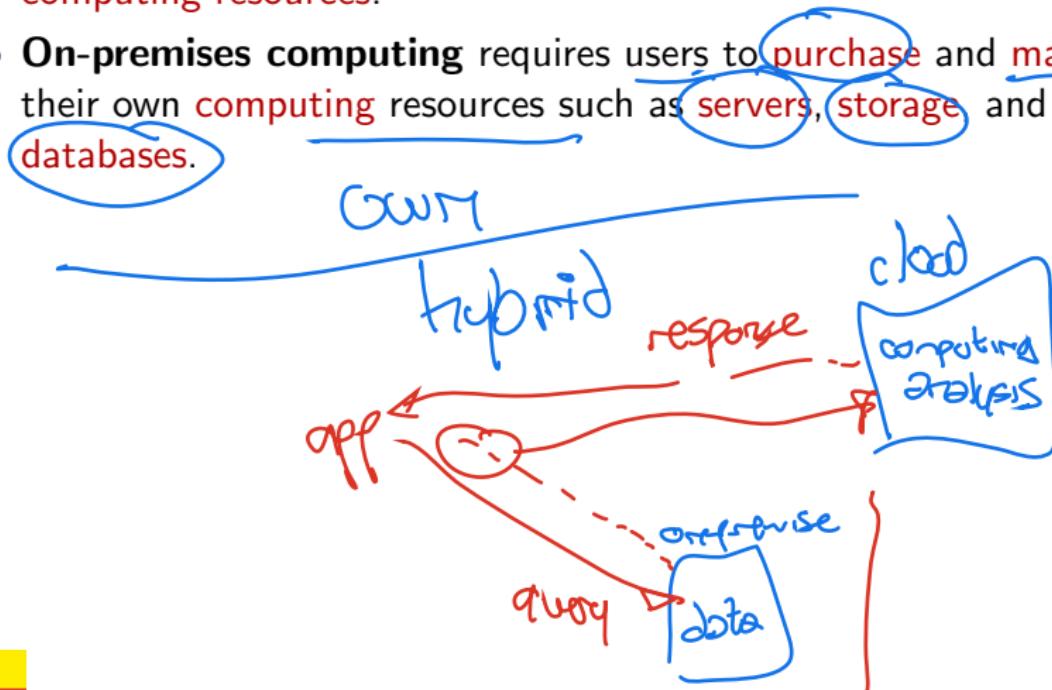
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- On-premises computing requires users to purchase and maintain their own computing resources such as servers, storage, and databases.



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Pros & Cons of Cloud Computing

• Pros:

- **Cost-Effective:** Cloud computing is a cost-effective way to access computing resources.
- **Scalable:** Cloud computing is a scalable way to access computing resources.
- **Flexible:** Cloud computing is a flexible way to access computing resources.

• Cons:

- **Dependency:** One of the main cons of cloud computing is dependency on external providers. If the provider goes down or becomes unavailable, it can affect your entire system.
- **Cost:** While cloud computing can be cost-effective in the long run, there are initial setup costs and ongoing costs for storage, processing power, and bandwidth.
- **Security:** Security is a major concern with cloud computing. Data stored in the cloud is vulnerable to hacking and other security threats.
- **Loss of Control:** When you use cloud computing, you lose some level of control over your data and how it is used. You have to rely on the provider's policies and practices.
- **Regulatory Compliance:** Depending on where your data is stored, you may need to comply with various regulations and laws, such as GDPR or CCPA. This can add complexity and cost to your operations.



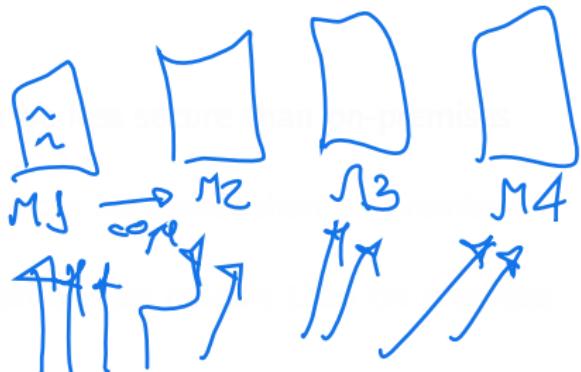
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2M 5Gb
HD 15b → 10 Gb
2 Tb



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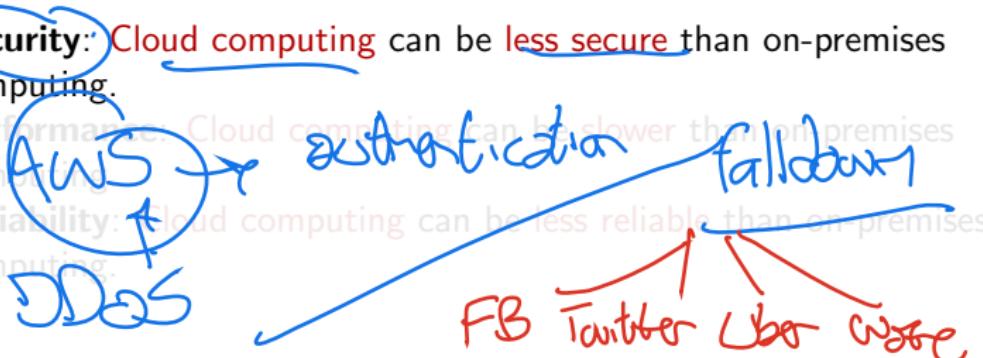
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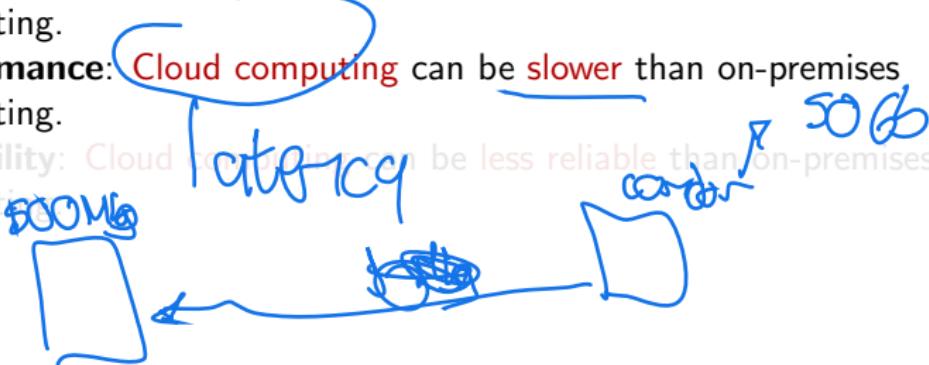
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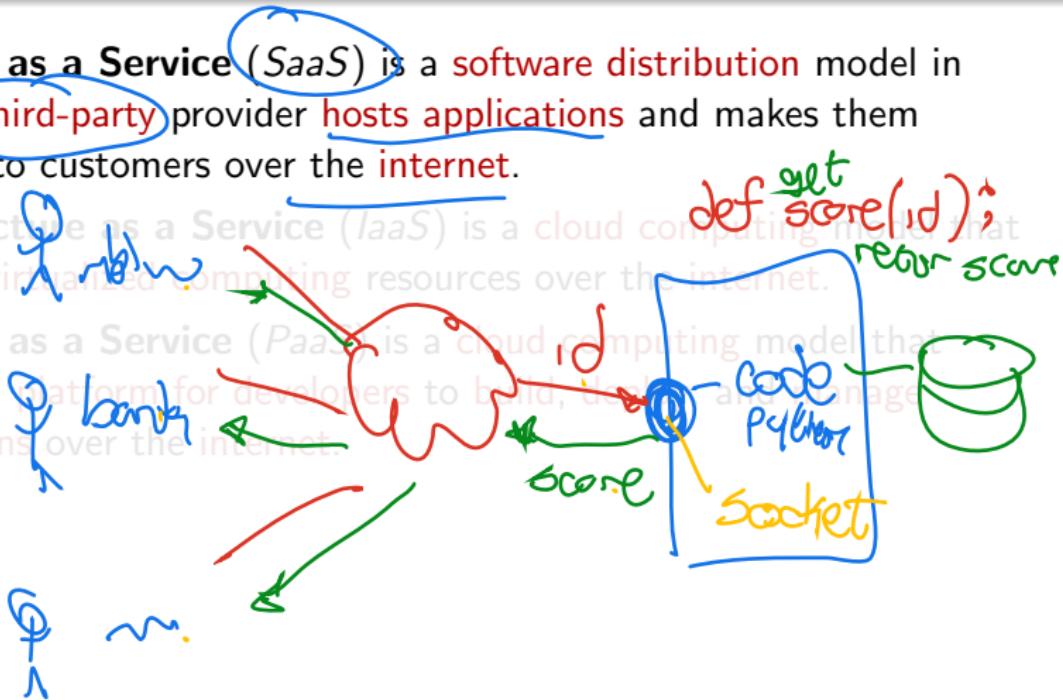


SaaS Vs. IaaS Vs. PaaS

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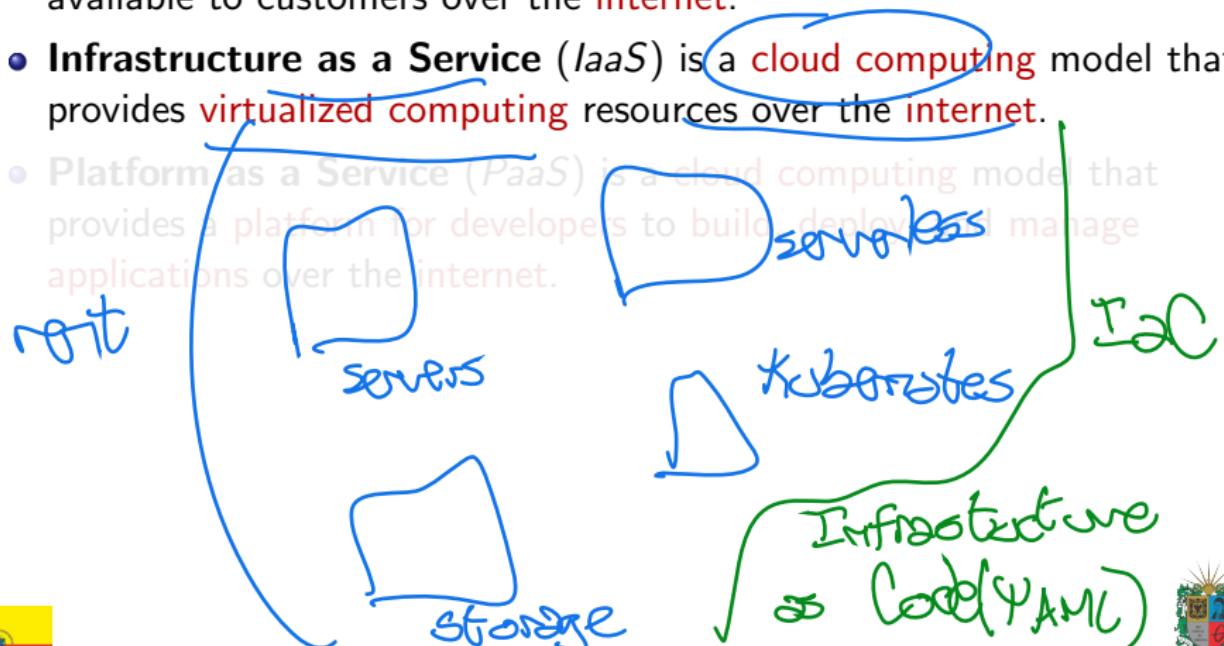
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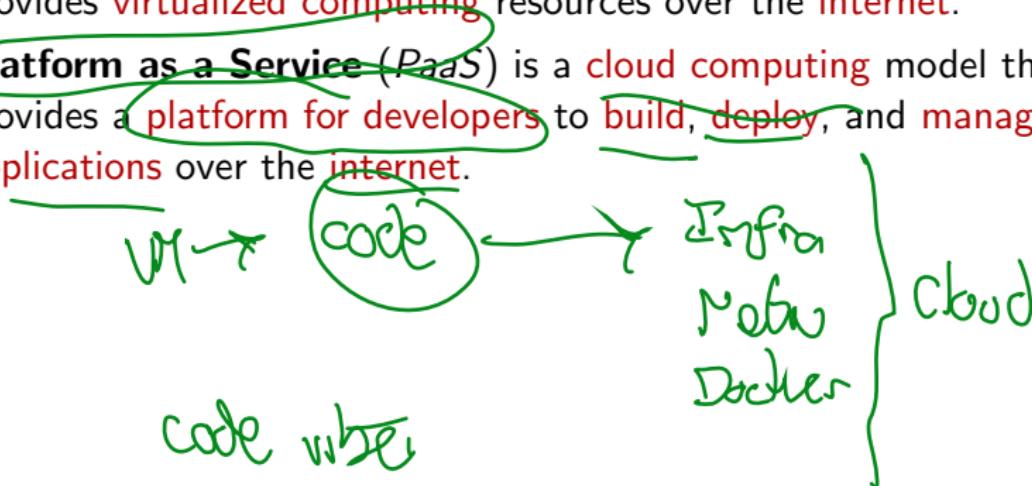
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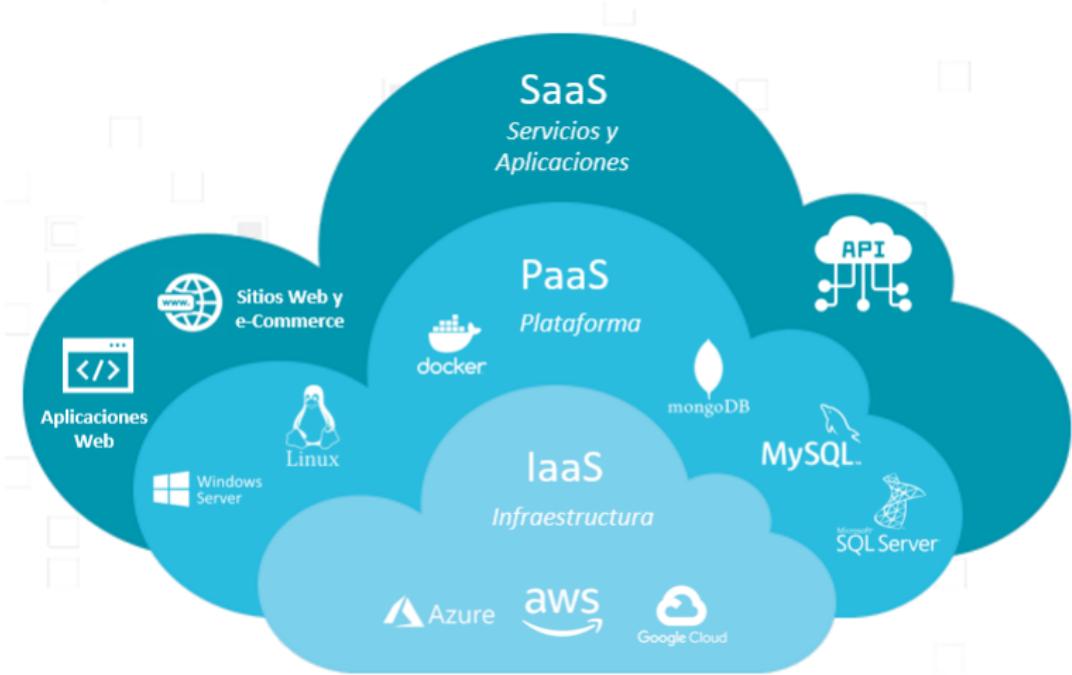


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Cloud Levels

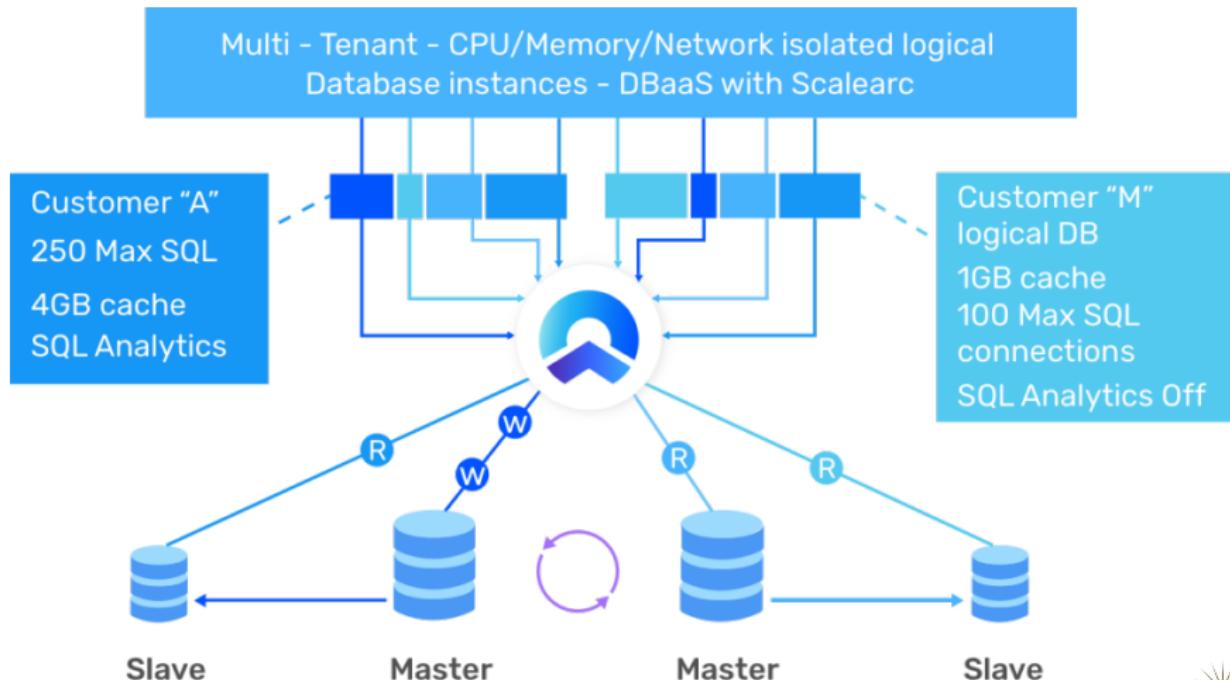


DataBases as a Service

Database as a Service (DBaaS) is a **cloud computing model** that provides **database services** over the **internet**.



Case of Study: DBaaS Custom for Clients



Localhost

- **Localhost** is a **hostname** that refers to the **local computer** that a **program** is **running on**.
- **Localhost** is used to **access the services** that are **running on** the **local computer**.
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Monolithic Architecture

- **Monolithic Architecture** is a **software architecture** in which all the components of the software are **combined** into a **single program**.
- **Monolithic Architecture** is a **traditional software architecture** that was used to **build large** and **complex software systems**.
- **Monolithic Architecture** is a simple and **easy-to-understand** software architecture that is used to **build software systems** that do **not require** high scalability and flexibility.



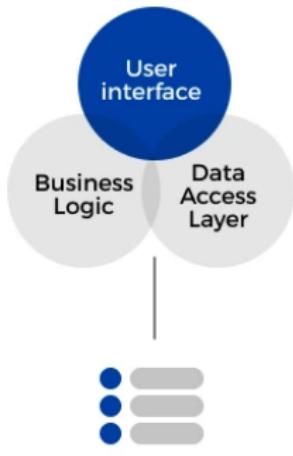
Microservices Architecture

- **Microservices Architecture** is a **software architecture** in which the components of the software are broken down into **small, independent services**.
- **Microservices Architecture** is a **modern software architecture** that is used to **build large and complex software systems**.
- **Microservices Architecture** is a **flexible and scalable software architecture** that is used to **build software systems** that require high scalability and flexibility.

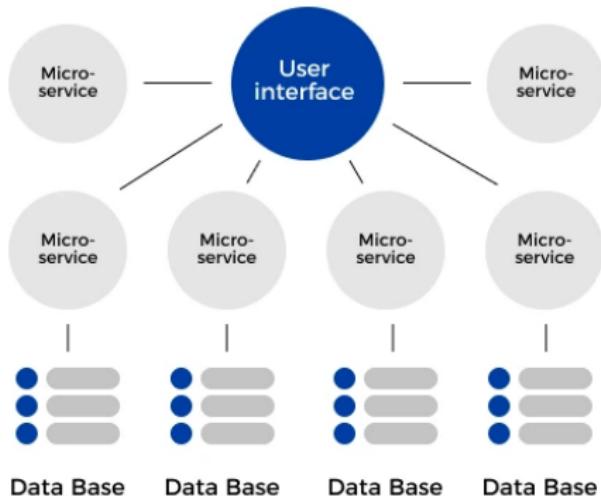


Monolithic Architecture Schema

MONOLITHIC ARCHITECTURE



MICROSERVICE ARCHITECTURE



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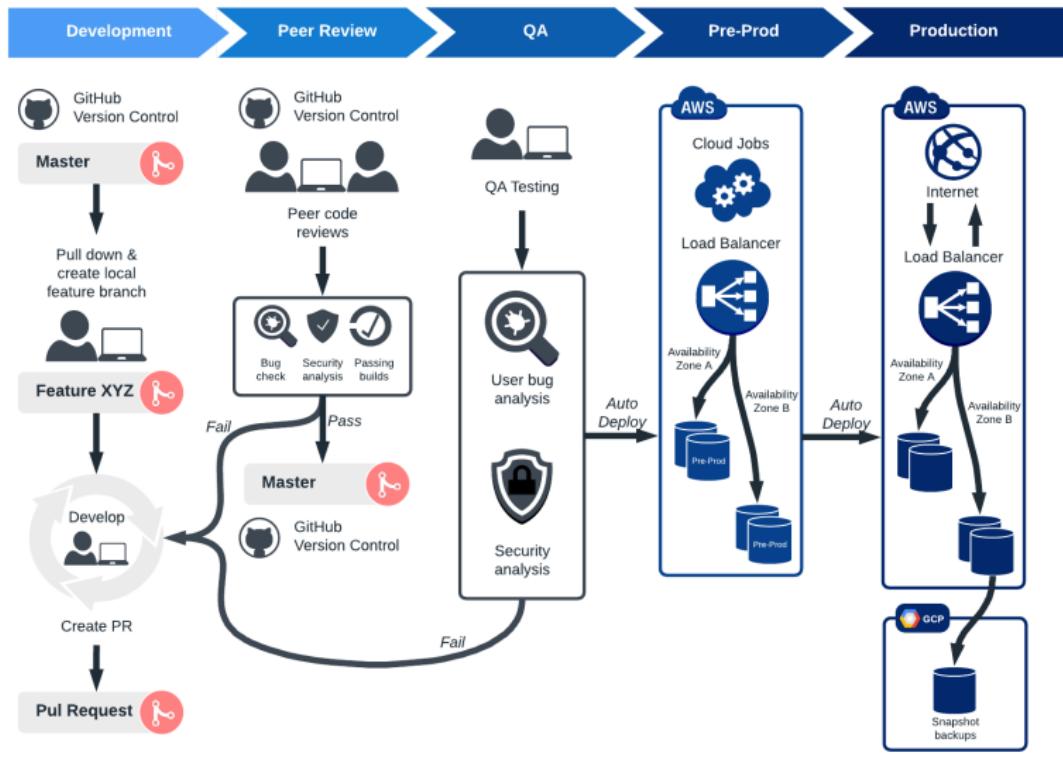


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Development Workflow using CI/CD



Containers and Docker

- **Containers** are a **lightweight** and **portable** way to **package software**.
- **Containers** are a method to **isolate applications** from the underlying system.
- Docker is a **platform** that allows developers to **build**, **ship**, and **run** containers.

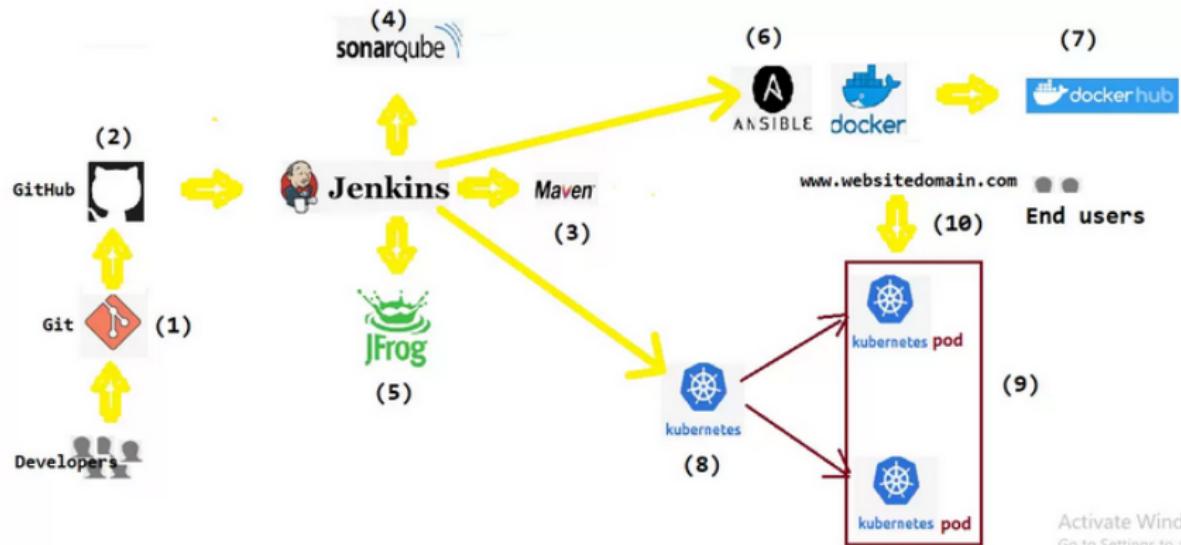


Containers and Docker

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From Code to Docker



Outline

1 Software Components and Applications

2 Glosary

3 DataBase Classification

4 Relational Database Design

5 Entity-Relation Model (MER)

6 DataBase Management Systems — DBMS

7 DataBases Infrastructure

8 DevOps

9 Data Engineering



What is Data Engineering?

- **Data Engineering** is the aspect of data science that focuses on practical applications of **data collection** and **analysis**.
- **Data Engineers** are responsible for **building** and **maintaining the architecture** that allows data scientists to perform their work.
- **Data Engineering** is a set of operations aimed at creating interfaces and mechanisms for the **flow** and **access of data**.



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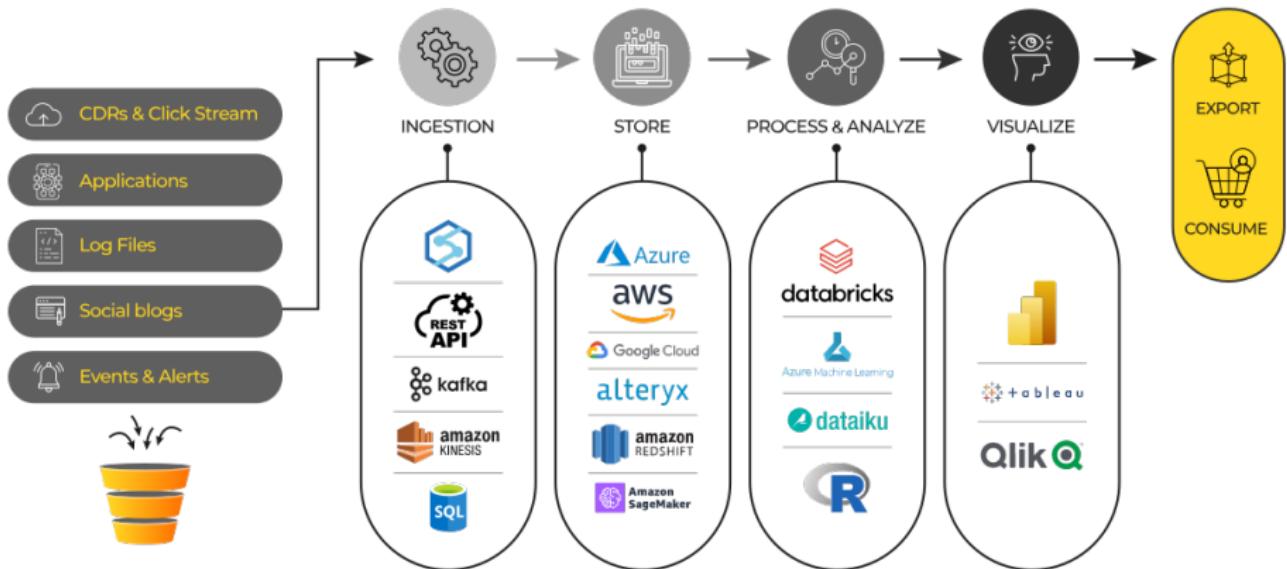


Why is important Data Engineering?

- **Data Engineering** is the foundation of the **high-quality data** that is necessary for **effective data science**.
- **Data Engineering** is the process of **collecting, transforming, and storing data** in a way that's accessible and easy to analyze.



Data Engineering Architecture



Case of Study: Dashboards



Data Science

- **Data Science** is the process of extracting knowledge from data.
- Data Science is the process of analyzing and interpreting complex digital data.
- Data Science is the process of creating models that can predict future outcomes.
- Data Science is the process of creating visualizations to help understand data.



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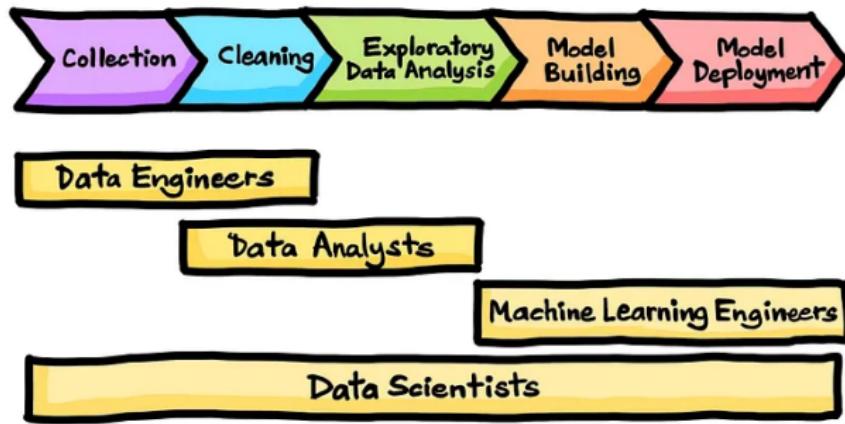
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Data Science Workflow

THE DATA SCIENCE PROCESS



DBOps vs Data Engineer

- **DBOps** is responsible for the **operation of the database**.
- **DBOps** is responsible for the **performance of the database**.
- **DBOps** is responsible for the **security of the database**.
- **Data Engineer** is responsible for the **data architecture**.
- **Data Engineer** is responsible for the **data quality**.
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How to improve data quality?

- **Data Quality** is the process of ensuring that **data** is **accurate**, **complete**, and **reliable**.
- **Data Quality** is the process of ensuring that **data** is **consistent** and **up-to-date**.
- **Data Quality** is the process of ensuring that **data** is **free from errors** and **inconsistencies**.
- **Data Quality** is the process of ensuring that **data** is of **high quality** and can be **trusted**.
- **Data Quality** is the process of ensuring that **data** is **fit for purpose** and can be **used effectively**.



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Thanks!

Questions?



Repo: <https://github.com/EngAndres/ud-public/tree/main/courses/databases-ii>

