Relational Databases

Design Theory

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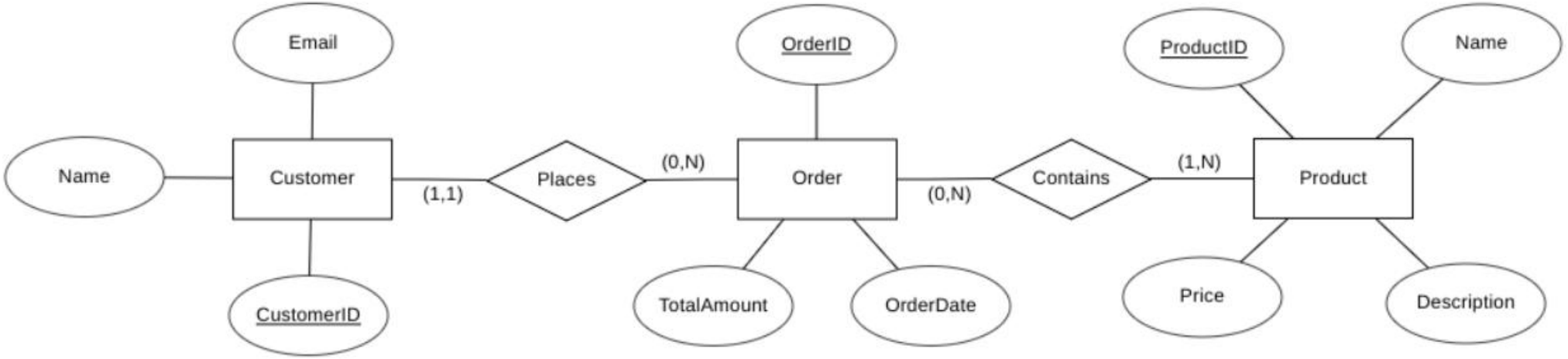
Quick Recap: Entity-Relationship Diagram

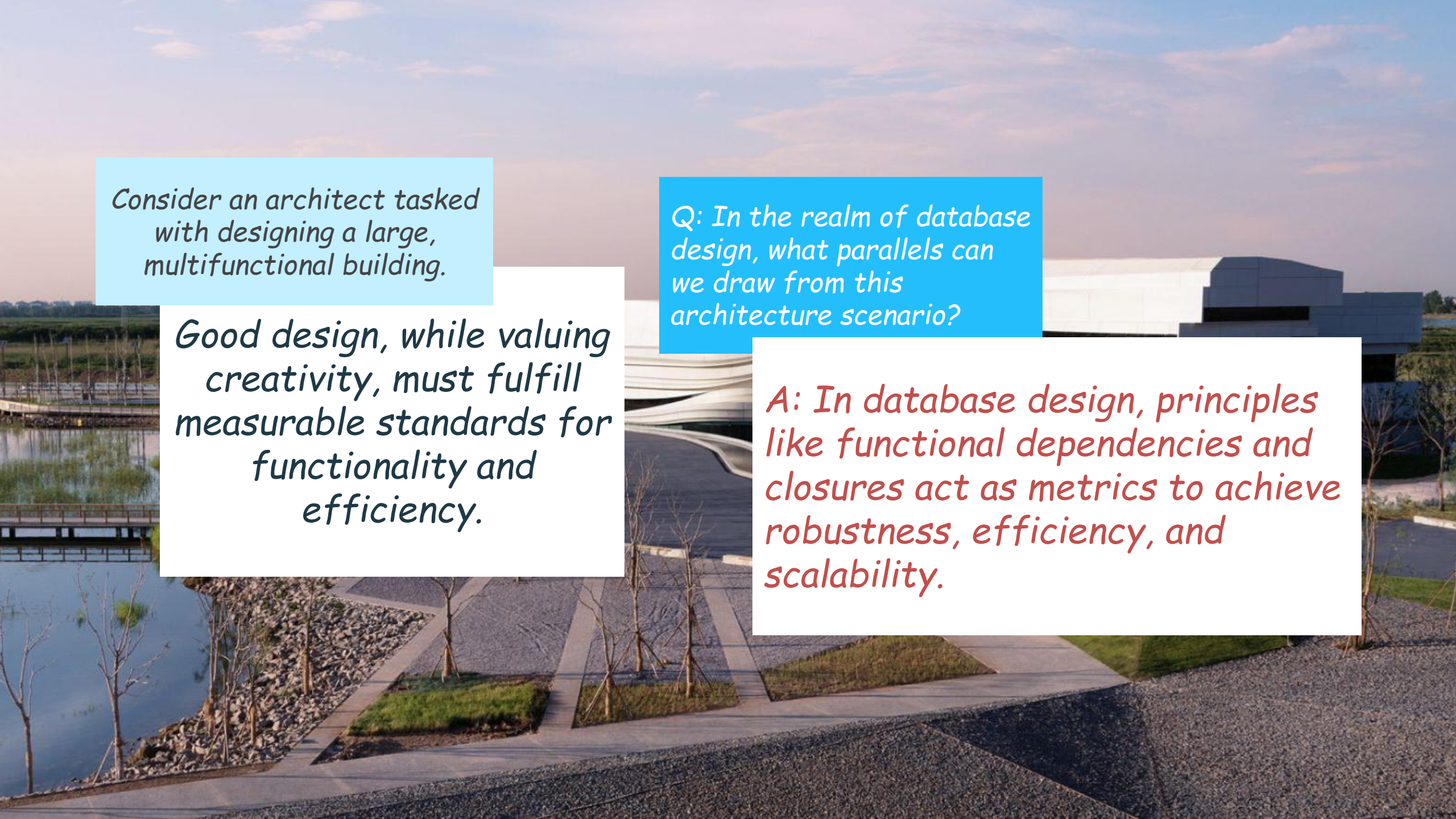
Key Concepts:

- ERDs are foundational in visualizing and structuring the data relationships in a database, facilitating clear communication and planning in the design process. They highlight entities, their attributes, and the relationships between them, crucial for understanding the database's conceptual layout.
- One-to-One, One-to-Many, Many-to-Many, Self-Referencing, and M-way are critical in ERDs. These relationships help in accurately modeling complex real-world interactions within the database.

ERD Example



- **Scenario:** Customer's Order History.



Consider an architect tasked with designing a large, multifunctional building.

Good design, while valuing creativity, must fulfill measurable standards for functionality and efficiency.

Q: In the realm of database design, what parallels can we draw from this architecture scenario?

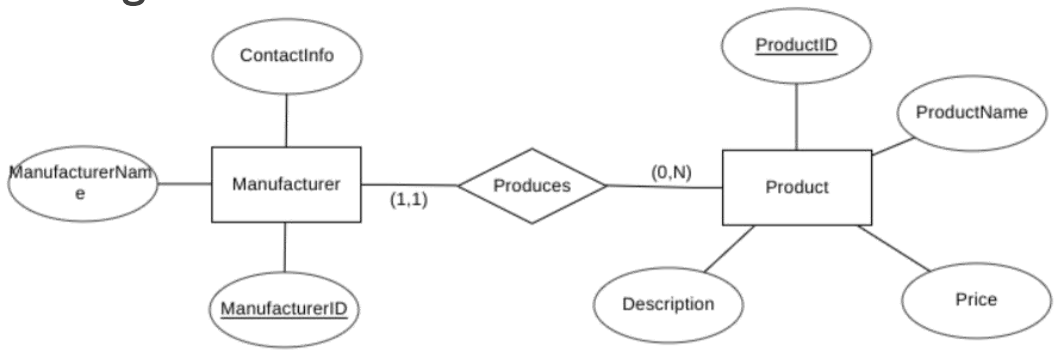
A: In database design, principles like functional dependencies and closures act as metrics to achieve robustness, efficiency, and scalability.

Transfroming ER Models to Relational Schemas

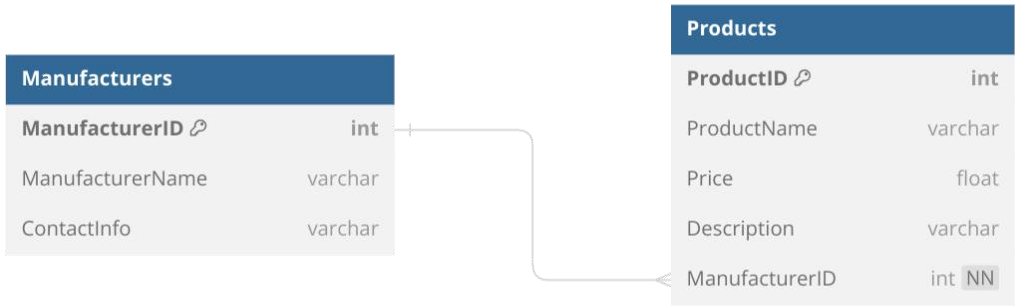
Key Points:

- **Entity Conversion:** Each entity in the ER model becomes a table in the schema.
- **Relationship Handling:** Relationships in ER models are translated into foreign keys and join tables.
- **Attribute Translation:** Attributes of entities in the ER model become the columns of the tables in the schema.

ER Diagram:



Relational Schema:



Best Practices:

- **Consistency:** Keep names and types consistent during the transition.
- **Integrity Constraints:** Enforce data integrity through constraints derived from the ER model (e.g., not null, unique).

Normalisation Consideration

- The schema often needs normalisation to ensure efficiency and data integrity.

What Makes a Good Data Model?

Efficient Representation of Data Relationships

- A good data model accurately represents the relationships between different data entities, ensuring clarity and logical structure.

Minimised Redundancy

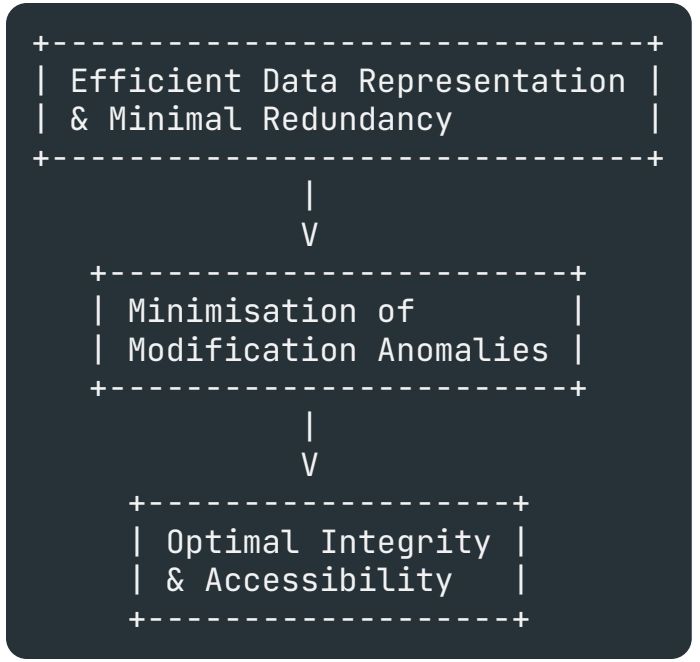
- Reduces unnecessary repetition of data across the database, enhancing efficiency and storage utilization.

Minimised Modification Anomalies

- Effectively manages and minimizes potential errors in data modification, such as update, insertion, and deletion anomalies.

Data Integrity and Accessibility

- Maintains high data integrity and provides ease of access and use, making the database reliable and user-friendly.



Learning Path

1st

What are Modification Anomalies?

- **The Foundation:** Before managing modification anomalies, it's essential to know what they are. These are issues in databases that lead to inconsistent data during Insertions, Deletions, and Updates.
- **Why It Matters:** Identifying these anomalies is the first critical step. It's about understanding the challenges in database operations to develop effective strategies for handling them.

Learning Path

1st

What are Modification Anomalies?

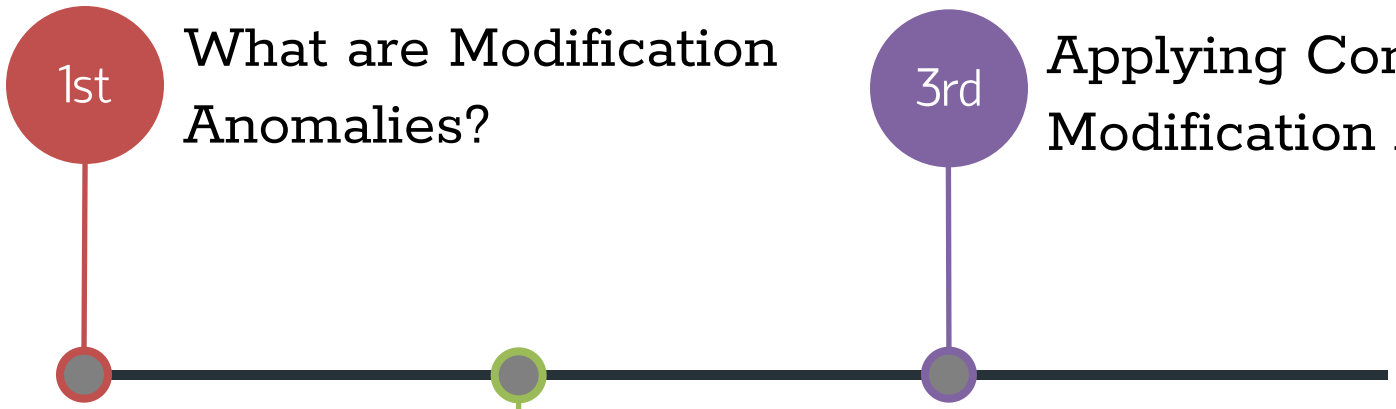
- **Equipping Ourselves:** To handle modification anomalies, we equip ourselves with two key concepts: Functional Dependencies and Closure.
- **Functional Dependencies:** This concept helps us understand how one set of data in our database affects another. It's vital for identifying potential spots where anomalies might occur.
- **Closure:** As an extension, closure lets us see the full extent of an attribute set's influence. It's key in getting a complete picture of our data's interrelationships, enhancing our ability to spot and address anomalies.

2nd

Key Concepts for Identifying Modification Anomalies

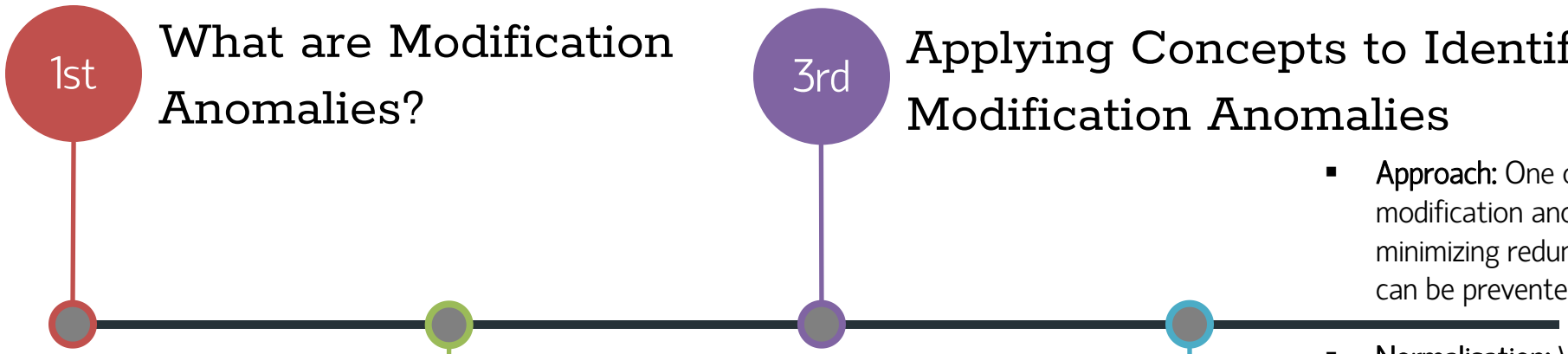
Functional Dependencies and Closure

Learning Path



- **Hands-On Application:** We'll use Functional Dependencies and Closure to analyse real-life examples, pinpointing where anomalies are likely to arise and exploring ways to address them.

Learning Path



1st

What are Modification Anomalies?

2nd

Key Concepts for Identifying Modification Anomalies

Functional Dependencies and Closure

3rd

Applying Concepts to Identify Modification Anomalies

- **Approach:** One of the primary causes of modification anomalies is redundancy in data. By minimizing redundancies, many of these anomalies can be prevented.
- **Normalisation:** We'll learne how normalisation techniques effectively reduce redundancy, thereby enhancing data integrity and stability, using practical examples.

4th

Minimising Redundancies to Prevent Modification Anomalies

Next Lecture

Learning Path

1st

What are Modification Anomalies?

- **The Foundation:** Before managing modification anomalies, it's essential to know what they are. These are issues in databases that lead to inconsistent data during Insertions, Deletions, and Updates.
- **Why It Matters:** Identifying these anomalies is the first critical step. It's about understanding the challenges in database operations to develop effective strategies for handling them.

Modification Anomalies

Key Points:

- Modificaiton Anomalies are unintended side effects in the database system, often arising from inadequate or flaw design.
- These lead to inconsistent data, redundant or duplicated entries and impact in overall efficiency and performance of the database

Types of Anomalies

- **Insertion Anomaly**, **Deletion Anomaly** and **Update Anomaly**

Insertion Anomalies

Definition

- An insertion anomaly occurs in a database when the addition of new data is hindered or results in incomplete records due to the reliance on other related data being present.

Example Scenario

- **Context:** In an e-commerce database with combined product and supplier details, adding a new supplier without associated products leads to records with NULL values for product columns.

Product ID	Product Name	Supplier ID	Supplier Name	Supplier Contact
1001	Solar String Lights	S01	EcoLights Co.	+1234567890
NULL	NULL	S03	NewEco Inc.	+1122334455

Explanation

- In this scenario, adding 'NewEco Inc.' as a new supplier without a corresponding product creates entries with NULL values for product fields. This occurrence, typical in denormalized databases, exemplifies an insertion anomaly: you can add supplier details, but the absence of related product data leads to incomplete records.

Deletion Anomalies

Definition

- A deletion anomaly occurs when removing a record from a database inadvertently leads to the loss of additional, valuable data.

Example Scenario

- **Context:** With product details and their supplier information are stored in the same table. When the last product from a specific supplier is deleted, the supplier's details are also lost from the database

Product ID	Product Name	Supplier ID	Supplier Name	Supplier Contact
1001	Solar String Lights	S01	EcoLights Co.	+1234567890
1002	LED Lantern	S02	BrightLumen Inc.	+1987654321

Deletion Action

- Delete 'Solar String Lights' (the only product supplied by 'EcoLights Co.')

Product ID	Product Name	Supplier ID	Supplier Name	Supplier Contact
1002	LED Lantern	S02	BrightLumen Inc.	+1987654321

Explanation

- By deleting 'Solar String Lights', all information about its supplier 'EcoLights Co.' is also removed from the table. This deletion anomaly leads to the loss of important supplier details that might be needed for future reference or orders.

Update Anomalies

Definition

- Update anomalies occur when changes made to data in one part of a denormalized database are not consistently replicated in other related parts, leading to data inconsistencies or redundancies.

Example Scenario

- **Context:** Consider an database where each product's record includes supplier details. An update anomaly happens when changing a supplier's contact information in one product record does not automatically update the same information in other products supplied by the same supplier.

Product ID	Product Name	Supplier ID	Supplier Name	Supplier Contact
1001	Solar String Lights	S01	EcoLights Co.	+1234567890
1003	Eco Desk Lamp	S01	EcoLights Co.	Old Contact Info

Explanation

- In this example, updating the contact information for 'EcoLights Co.' in the record for 'Solar String Lights' doesn't update the same information for 'Eco Desk Lamp'. This inconsistency in supplier contact details across different product records is a classic update anomaly.

Learning Path

1st

What are Modification Anomalies?

- **Equipping Ourselves:** To handle modification anomalies, we equip ourselves with two key concepts: Functional Dependencies and Closure.
- **Functional Dependencies:** This concept helps us understand how one set of data in our database affects another. It's vital for identifying potential spots where anomalies might occur.
- **Closure:** As an extension, closure lets us see the full extent of an attribute set's influence. It's key in getting a complete picture of our data's interrelationships, enhancing our ability to spot and address anomalies.

2nd

Key Concepts for Identifying Modification Anomalies

Functional Dependencies and Closure

Functional Dependencies

Definition

- Functional Dependencies are relationships where one set of data in a database uniquely determines another set. These relationships are key to structuring databases effectively.
- **Importance:** Understanding FDs helps in creating logically organized and efficient databases.

Example Scenario

- Customer Table:

```
+------------+-------------+-----------------+
| CustomerID | Name        | Address         |
+------------+-------------+-----------------+
| 1001       | Alice Smith | 123 Apple Lane  |
| 1002       | Bob Jones   | 456 Berry Blvd. |
| 1003       | Carol White | 789 Cherry St.  |
+------------+-------------+-----------------+
```

- List of Dependencies:

```
CustomerID -> CustomerName, Address
```

E-Commerce Example

Scenario

- Product Table:

SKU Number	Name	Price	Description
SKU1234	Wireless Mouse	29.99	Ergonomic wireless mouse
SKU5678	Bluetooth Keyboard	49.99	Compact Bluetooth keyboard
SKU9101	USB-C Hub	39.99	4-port USB-C hub

- List of Dependencies:

```
SKU Number -> Name, Price, Description
```

Explanation

- A single SKU Number uniquely determines a product's Price, Name, Description, and Category.
- This dependency ensures consistent and reliable data across the database, which is essential for inventory management, customer experience, and analytics.

Identifying Functional Dependencies

The Process of Identifying Functional Dependencies

- Identifying FDs often involves looking for patterns and consistent relationships within your data.

- Example Scenario: (Sales Table)

Order ID	Order Date	Customer ID	Total Amount	Product ID
01001	2021-07-01	C123	150.00	P001
01002	2021-07-02	C124	200.00	P002
01003	2021-07-02	C125	250.00	P003

- Practical Tips:
  - **Unique Identifiers:** Start with primary keys or unique identifiers as they often determine other information.
  - **One-to-One Relationship:** Look for cases where one data element always corresponds to a specific value of another.
  - **Real-World Logic:** Apply your understanding of the real-world context. For instance, in a sales database, an 'Order ID' will determine 'Order Date' and 'Total Amount'."

- List of Dependencies:

```
Order ID -> Order Date, Customer ID, Total Amount, Product ID
```

Identifying Functional Dependencies (cont.)

- Example Scenario: (Sales Table)

Order ID	Product ID	Product Name	Customer ID	Customer Name	Order Total
O1001	P001	Wireless Mouse	C123	Alice	300.00
O1001	P002	Bluetooth Keyboard	C123	Alice	300.00
O1002	P002	Bluetooth Keyboard	C124	Bob	200.00
O1003	P003	USB-C Hub	C125	Carol	450.00
O1003	P001	Wireless Mouse	C125	Carol	450.00

- List of Dependencies:

```
Order ID -> Order Total, Customer ID, Customer Name
Product ID -> Product Name
Customer ID -> Customer Name
```

- The current table's structure, where Order ID and Product ID are in the same table without a clear functional dependency, can lead to data redundancy and complications in maintaining the database, as seen with repeated customer and order total information.
- In a well-structured database, a separate junction table or line items table would typically be used to appropriately represent this many-to-many relationship.

Learning Path

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What are Modification Anomalies?

- **Equipping Ourselves:** To handle modification anomalies, we equip ourselves with two key concepts: Functional Dependencies and Closure.
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- **Closure:** As an extension, closure lets us see the full extent of an attribute set's influence. It's key in getting a complete picture of our data's interrelationships, enhancing our ability to spot and address anomalies.

2nd

Key Concepts for Identifying Modification Anomalies

Functional Dependencies and Closure

Understanding Closure

What is Closure in Functional Dependencies?

- Closure in database theory, denoted as X+, refers to the complete set of attributes functionally determined by a given set of attributes X. It represents all data inferred from X.
- Point: Closure expands functional dependencies, revealing the full impact of a set of attributes within a table.

Example Scenario

CustomerID	Name	Address
C001	Alice Smith	123 Maple St
C002	Bob Johnson	456 Oak Ave
C003	Carol Davis	789 Pine Rd

- **Closure:**

Set of Attributes	Closure (X+)
CustomerID	Name, Address

- This means that knowing the CustomerID of any entry allows us to determine the corresponding customer's Name and Address uniquely.
- This closure indicates a direct and exclusive relationship between CustomerID and the two other attributes, highlighting the role of CustomerID as a potential primary key for this table.

Identifying Superkeys and Keys

Closure and Superkeys

- A superkey is a set of one or more attributes that can uniquely identify each record in a table. Closures help us find these superkeys.

Example Scenario

Customer ID	Name	Address	Email
C001	Alice Smith	123 Maple St	alice@example.com
C002	Bob Johnson	456 Oak Ave	bob@example.com
C003	Carol Davis	789 Pine Rd	carol@example.com

- Closure:

Attribute Set	Closure (All Determined Attributes)	Is Superkey?
CustomerID	CustomerID, Email, Name, Address	Yes

- In a Customer table with CustomerID, Email, Name, and Address, if the closure of CustomerID includes all these attributes, then CustomerID is a superkey.

Identifying Superkeys and Keys (cont.)

Example Scenario

Customer ID	Name	Address	Email
C001	Alice Smith	123 Maple St	alice@example.com
C002	Bob Johnson	456 Oak Ave	bob@example.com
C003	Carol Davis	789 Pine Rd	carol@example.com

Refining Superkeys to Candidate Keys

- A candidate key is the smallest possible superkey – it cannot have any redundant attributes.
- **Closure:**

Attribute Set	Closure (All Determined Attributes)	Is Superkey?	Is Key?
CustomerID	CustomerID, Email, Name, Address	Yes	Yes (Candidate Key)

- If 'CustomerID' alone can uniquely identify every record (closure of 'CustomerID' is the entire set of table attributes), then 'CustomerID' is not just a superkey but also a candidate key. It's the minimal attribute set needed for unique identification."
- **Additional Consideration:** If adding Email to CustomerID doesn't expand the closure beyond the table's attributes, then (CustomerID, Email) is not a candidate key due to its non-minimality.

Utilising Closures on Complex Example

Order Details Example

OrderID	CustomerID	ProductID	OrderDate	Quantity	Price
O101	C001	P001	2021-01-01	2	20.00
O102	C002	P002	2021-01-02	1	15.00
O103	C003	P003	2021-01-03	5	10.00

- Closure:

Attribute Set	Closure (All Determined Attributes)	Is Superkey?
OrderID	OrderID, CustomerID, ProductID, OrderDate, Quantity, Price	Yes
CustomerID	CustomerID	No
ProductID	ProductID	No
OrderID, ProductID	OrderID, CustomerID, ProductID, OrderDate, Quantity, Price	Yes

Utilising Closures on Complex Example

Order Details Example

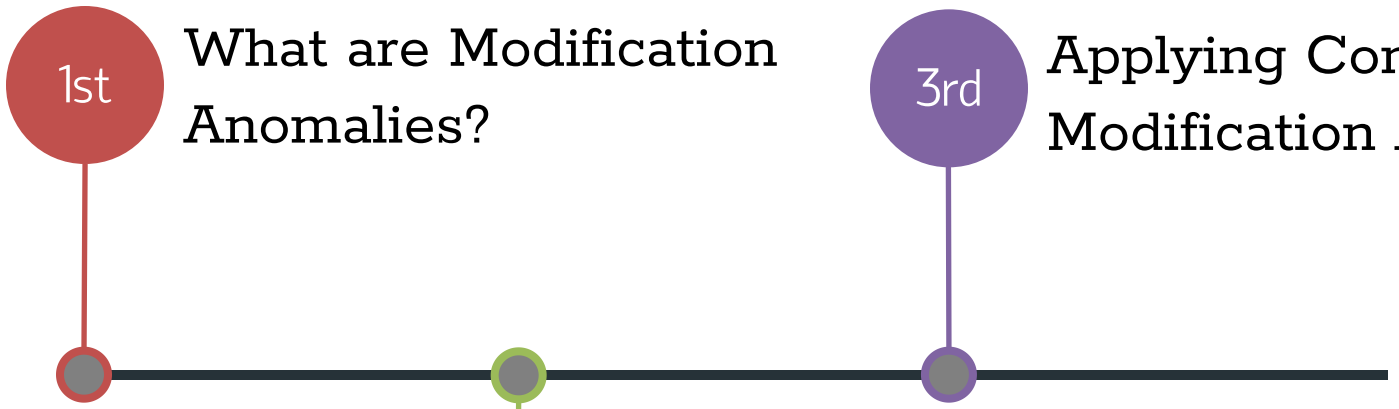
OrderID	CustomerID	ProductID	OrderDate	Quantity	Price
O101	C001	P001	2021-01-01	2	20.00
O102	C002	P002	2021-01-02	1	15.00
O103	C003	P003	2021-01-03	5	10.00

- Closure:

Attribute Set	Closure (All Determined Attributes)	Is Superkey?	Is Key?
OrderID	OrderID, CustomerID, ProductID, OrderDate, Quantity, Price	Yes	No
CustomerID	CustomerID	No	No
ProductID	ProductID	No	No
OrderID, ProductID	OrderID, CustomerID, ProductID, OrderDate, Quantity, Price	Yes	Yes (Candidate Key)

- OrderID alone is a superkey but not a candidate key as it's not minimal.
- CustomerID and ProductID alone do not determine all attributes, hence not superkeys.
- The combination (OrderID, Product ID) is both a superkey and a candidate key, being minimal yet determining all table attributes.

Learning Path



- **Hands-On Application:** We'll use Functional Dependencies and Closure to analyse real-life examples, pinpointing where anomalies are likely to arise and exploring ways to address them.

Recap and Beyond: Functional Dependencies and Closures

Functional Depedencies

- **Focus:** This is about the relationship between sets of attributes in a database. Specifically, it indicates that if you know the value of one set of attributes, you can determine the value of another set.
- **Modification Anomalies:** FDs identify potential **update anomalies**. By structuring tables based on FDs, update anomalies can be minimized, as each piece of information is stored only once and updated consistently.

Closure

- **Focus:** Closure involves identifying all the attributes that a given set of attributes can functionally determine. It extends the concept of functional dependencies to a broader set of attributes.
- **Modification Anomalies:** Closures help prevent **insertion and deletion anomalies**. By understanding which attributes determine others, database designers can organize tables to allow independent data entry (minimizing insertion anomalies) and prevent unintended data loss (minimizing deletion anomalies).

Functional Dependencies: Identifying Update Anomalies

Order Table Example

CustomerID	CustomerName	Address	OrderID	OrderDate	OrderAmount
C001	Alice Smith	123 Apple Street	O100	2021-07-15	$150
C001	Alice Smith	123 Apple Street	O101	2021-07-20	$200
C002	Bob Johnson	456 Berry Avenue	O102	2021-07-18	$250

Functional Dependency and Anomaly Analysis

Attribute Set	Functional Dependency	Anomaly Detection
CustomerID	CustomerID → CustomerName, Address	Potential Update Anomaly if `CustomerName` or `Address` varies for the same `CustomerID`
OrderID	OrderID → OrderDate, OrderAmount, CustomerID	No apparent anomaly; `OrderID` uniquely determines `OrderDate`, `OrderAmount`, and `CustomerID`

- **Anomaly Detection Pointer:** In summary, seeing a supposed-to-be unique identifier like CustomerID and OrderID repeating in a dataset is a flag for a potential anomaly that should be investigated further.
- **Scenario:** Imagine a scenario where, in future data entries, 'CustomerName' varies for the same 'CustomerID', which would be an update anomaly. This inconsistency would indicate a violation of the functional dependency ('CustomerID' → 'CustomerName', 'Address').

Closure and Keys: Identifying Insertion Anomalies

Product Table Example

ProductID	ProductName	SupplierID	SupplierName
P001	Laptop	S001	TechCorp
P002	Phone	S002	MobileInc

Closure and Key Analysis

Attribute Set	Closure (All Determined Attributes)	Is Superkey?	Is Key?	Anomaly Indication
ProductID	ProductID, ProductName	No	No	Potential for Insertion Anomaly (Incomplete data without `SupplierID` and `SupplierName`)
SupplierID	SupplierID, SupplierName	No	No	No apparent anomaly
ProductID, SupplierID	ProductID, ProductName, SupplierID, SupplierName	Yes	Yes (Candidate Key)	No anomaly

- **Anomaly Detection Pointer:** Watch for missing data in entries. If key attributes like 'SupplierID' and 'SupplierName', expected from the closure of 'ProductID', are absent in new records, it suggests an insertion anomaly.
- **Scenario:** Imagine adding a new product (P003) without 'SupplierID' and 'SupplierName' exemplifies an insertion anomaly. This case violates the closure rule where 'ProductID' and 'SupplierID' together should determine complete product details, including 'ProductName' and 'SupplierName'.

Closure and Keys: Identifying Deletion Anomalies

Product Table Example

SupplierID	SupplierName	ProductID	ProductName
S001	TechCorp	P001	Laptop
S001	TechCorp	P002	Phone
S002	MobileInc	P003	Tablet

Closure and Key Analysis

Attribute Set	Closure (All Determined Attributes)	Is Superkey?	Is Key?	Anomaly Detection
SupplierID	SupplierID, SupplierName, ProductID, ProductName	Yes	No	Deletion of `SupplierID` could remove all linked products (Deletion Anomaly)
ProductID	ProductID, ProductName	No	Yes	No apparent anomaly

- **Anomaly Detection Pointer:** Pay attention to how interconnected attributes are based on closures. Deleting a record that's a key part of a closure can lead to unintended loss of crucial related information, representing a deletion anomaly.
- **Scenario:** Imagine deleting a supplier (like S001) could lead to the deletion of all related products (P001, P002). This would be a deletion anomaly as the removal of a supplier record inadvertently leads to the loss of important product data.

Learning Path

1st

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2nd

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Functional Dependencies and Closure

3rd

Applying Concepts to Identify Modification Anomalies

- **Approach:** One of the primary causes of modification anomalies is redundancy in data. By minimizing redundancies, many of these anomalies can be prevented.
- **Normalisation:** We'll learne how normalisation techniques effectively reduce redundancy, thereby enhancing data integrity and stability, using practical examples.

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Minimising Redundancies to Prevent Modification Anomalies

Next Lecture

Recap and Key Takeaways

- A good data model is characterized by its efficiency in representing data relationships and its effectiveness in minimizing modification anomalies, ensuring data consistency and integrity across the database.
- Functional dependencies and closure serve as crucial metrics for identifying potential anomalies. These insights guide database design, helping to structure data in a way that enhances reliability and scalability while minimizing redundancy and data anomalies.

```
| CustomerID | CustomerName    | Address               |
|------------|-----------------|-----------------------|
| C001       | Alice Smith     | 123 Apple Street      |
| C002       | Bob Johnson     | 456 Berry Avenue      |
| C001       | Alice Smith     | 789 Cherry Lane       | <!-- Anomaly -->
```

- An anomaly is observed with CustomerID C001. It is associated with two different addresses ('123 Apple Street' and '789 Cherry Lane'), which violates the functional dependency. This inconsistency suggests an update anomaly.

Preparing for Normalisation:

- Next Lecture Preview:
  - Understand key methods for organizing database structures to enhance efficiency and minimise modification anomalies.
  - Explore various normalization forms and their significance in optimizing database design and functionality.

In what ways do you think the concepts of superkeys and candidate keys are essential for maintaining the integrity of a relational database?