# Relational Model

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# Overview

# Content

- Relational Model - definition, structure, terminology.
- Candidate, Primary and Foreign Keys.
- Entity and Referential Integrity.

# Learning Outcomes

- Understand what is the relational model.
- Familiar with each component in the model.
- Point out keys in a given relaitonal model.
- Design primary and foreign keys.
- Understand the basic concept of referential integrity.

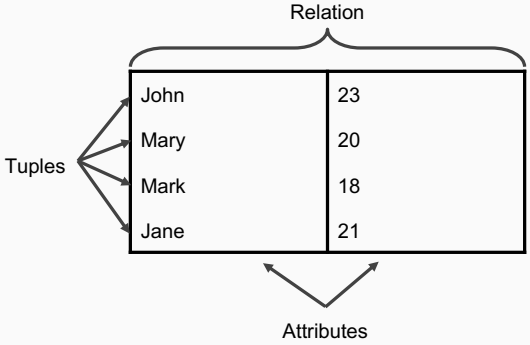
# Relational Model

# What is the Relational Model?

- An approach to managing data using a structure and language consistent with:
  - *First-order predicate logic (FOL)*
- Originally introduced by E.F. Codd in his paper in 1970:
  - “A Relational Model of Data for Large Shared Databanks”
- The foundation for most (but not all) modern DBMS.
- Provide a declarative method for specifying data and queries.
  - What info DB contains and what info users want
- Chapter 4 of the DB book.

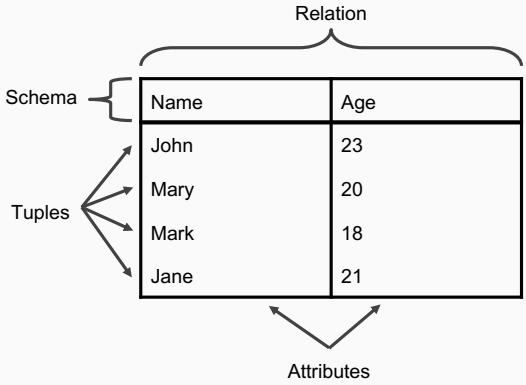
# Relational Data Structure

- Data is stored in **relations** which are tables with columns and rows.
- An **attribute** of a relation is a column in the table.
- A relation is a set of **tuples**.
  - e.g., a tuple *(John, 23)*.



# Relational Data Structure

- Each relation has a **schema**.
  - Schemas define the relation's attributes.
  - Sometimes called **headings**.
- Each attribute has a corresponding **domain**.
  - i.e., A set of possible values.



# How to represent relations

Student

| Name | Age |
|---|---|
| John | 23 |

- Attribute: the name of each attribute, e.g., Age
- Schema: $(A_1, \ldots, A_n)$
  - $A_i$: attributes in the relation $R$.
  - E.g., $(Name, Age)$.
- Relation: $R(A_1, \ldots, A_n)$
  - $R$: the name of a relation.
  - E.g., $Student(Name, Age)$
- Tuples:
  - Named: $\{(A_1 : V_1^1, \ldots, A_n : V_n^1), \ldots, (A_1 : V_1^m, \ldots, A_n : V_n^m)\}$
  - E.g., $\{(Name : John, Age : 23)\}$
  - Unnamed: $\{(V_1^1, \ldots, V_n^1), \ldots, (V_1^m, \ldots, V_n^m)\}$

# Relational Data Structure

More formally:

- A relational schema is a set of attributes.
- A tuple assigns a value to each attribute in the schema.
- A relation is a set of tuples with the same schema.

Student

| Name | Age |
|---|---|
| John | 23 |
| Mary | 20 |
| Mark | 18 |

- Schema: ?
- Tuples: ?

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- Schema: $(Name, Age)$
- Tuples: $\{(Name : John, Age : 23), (Name : Mary, Age : 20), (Name : Mark, Age : 18)\}$

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| Name | Age |
|---|---|
| John | 23 |
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- Schema: $(Name, Age)$
- Tuples: $\{(Name : John, Age : 23), (Age : 20, Name : Mary), (Name : Mark, Age : 18)\}$

# Terminology

- **Degree of a relation:** the number of attributes in the relational schema, i.e., how many columns.
- **Cardinality of a relation:** the number of tuples in a relation, i.e., how many rows.

# Example

Employee

| ID | Name | Salary | Department |
|---|---|---|---|
| M139 | John Smith | 18000 | Marketing |
| M140 | Mary Jones | 22000 | Marketing |
| A368 | Jane Brown | 22000 | Accounts |
| P222 | Mark Brown | 24000 | Personnel |
| A367 | David Jones | 20000 | Accounts |

- What are the attributes?
- What is the schema?
- How to represent this relation?
- What is the degree of this relation?
- What is the cardinality of this relation?

# Example

- Attributes: ID, Name, Salary, Department.
- Schema: $(ID, Name, Salary, Department)$
- Relation: $Employee(ID, Name, Salary, Department)$
- Relation:$\{(M139, JohnSmith, 18000, Marketing),$
  $(M140, MaryJones, 22000, Marketing),$
  $(A368, JaneBrown, 22000, Accounts),$
  $(P222, MarkBrown, 24000, Personnel),$
  $(A367, DavidJones, 20000, Accounts)\}$
- Degree: 4
- Cardinality: 5

# Properties

- Each relation has a distinct name.
- Each cell contains exactly one single value.
- Each attribute has a distinct name.
- The values of an attribute are all from the same domain.
- The order of attributes has no significance.
- The order of tuples has no significance.

# Problems without DBMS

- No standards.
- Incompatible file format.
- Data duplication.
- Data dependence.
- Fixed queries.
- Concurrency.
- Security.
- No theoretical foundations.

# Data duplication

Employee

| ID | Name | Salary | Department |
|---|---|---|---|
| M139 | John Smith | 18000 | Marketing |
| M140 | Mary Jones | 22000 | Marketing |
| A368 | Jane Brown | 22000 | Accounts |
| P222 | Mark Brown | 24000 | Personnel |
| A367 | David Jones | 20000 | Accounts |
| M140 | Mary Jones | 22000 | Marketing |

# Data duplication

Employee

| ID | Name | Salary | Department |
|---|---|---|---|
| M139 | John Smith | 18000 | Marketing |
| M140 | Mary Jones | 22000 | Marketing |
| A368 | Jane Brown | 22000 | Accounts |
| P222 | Mark Brown | 24000 | Personnel |
| A367 | David Jones | 20000 | Accounts |
| A369 | Mary Jones | 21000 | Accounts |

# Candidate Keys

- SuperKey: an attribute, or a set of attributes, that uniquely identifies a tuple within a relation.
- Candidate Key: a superkey such that no proper subset is a superkey within the relation.

**Definition (Candidate Key)**

A set of attributes $\mathcal{K}$ is a candidate key for a relation $\mathcal{R}$ iff

- In each tuple of $\mathcal{R}$, the values of $\mathcal{K}$ uniquely identify that tuple. (*Uniqueness*)
- There is no subset of $\mathcal{K}$ can uniquely identify the tuples in $\mathcal{R}$. (*Irreducibility*)

# Example: Candidate Keys

Office

| OfficeID | Name | Country | Postcode | Phone |
|---|---|---|---|---|
| O1001 | Headquarters | UK | W1 1AA | 0044 20 1545 3241 |
| O1002 | R&D Labs | UK | W1 1AA | 0044 20 1545 4984 |
| O1003 | US West | USA | 94130 | 001 415 665981 |
| O1004 | US East | USA | 10201 | 001 212 448731 |
| O1005 | Telemarketing | UK | NE5 2GE | 0044 1909 559862 |
| O1006 | Telemarketing | USA | 84754 | 001 385 994763 |

# Example: Candidate Keys

Candidate Keys: OfficeID, Phone, (Name, Postcode), (Name, Country)

| OfficeID | Name | Country | Postcode | Phone |
|---|---|---|---|---|
| O1001 | Headquarters | UK | W1 1AA | 0044 20 1545 3241 |
| O1002 | R&D Labs | UK | W1 1AA | 0044 20 1545 4984 |
| O1003 | US West | USA | 94130 | 001 415 665981 |
| O1004 | US East | USA | 10201 | 001 212 448731 |
| O1005 | Telemarketing | UK | NE5 2GE | 0044 1909 559862 |
| O1006 | Telemarketing | USA | 84754 | 001 385 994763 |

- You cannot necessarily infer the candidate keys based solely on the data in your table.
- You must use knowledge of the real-world to help

# Primary Keys and NULLs

- To identify each row in a table.
- Each relation must have a primary key to avoid data duplication.

**Definition (Primary Key)**
A primary key is selected from the set of candidate key to identify tuples in a relation.

- A NULL indicates a missing or unknown value in a relation.
  - Is a NULL the same as 0?
  - Is a NULL the same as a blank space character?
  - Can primary keys contains a NULL value?

# Foreign Keys

Department

| DID | DName |
|---|---|
| 13 | Marketing |
| 14 | Accounts |
| 15 | Personnel |

Employee

| EID | EName | DID |
|---|---|---|
| 15 | John Smith | 13 |
| 16 | Mary Brown | 14 |
| 17 | Mark Jones | 13 |
| 18 | Jane Smith | NULL |

- What are the primary keys?
- What are the connections between these two relations?

# Foreign Keys

**Definition (Foreign Key)**

An attribute, or set of attributes $\mathcal{F}$ within one relation $\mathcal{R}_1$ is a foreign key, if it matches the candidate key in another relation.

**Definition (Referential Integrity)**

If $\mathcal{F}$ is a foreign key which connects the data in $\mathcal{R}_1$ to those in another relation $\mathcal{R}_2$, then each value of $\mathcal{F}$ must:

- matche a primary/candidate key values in $\mathcal{R}_2$

or:

- be Null

# Foreign Keys

Department

| DID | DName |
|---|---|
| 13 | Marketing |
| 14 | Accounts |
| 15 | Personnel |

Employee

| EID | EName | DID |
|---|---|---|
| 15 | John Smith | 13 |
| 16 | Mary Brown | 14 |
| 17 | Mark Jones | 13 |
| 18 | Jane Smith | NULL |

- What is the foreign key?

# Foreign Keys

Department

| DID | DName |
|---|---|
| 13 | Marketing |
| 14 | Accounts |
| 15 | Personnel |

Employee

| EID | EName | DID |
|---|---|---|
| 15 | John Smith | 13 |
| 16 | Mary Brown | 14 |
| 17 | Mark Jones | 13 |
| 18 | Jane Smith | NULL |

- DID is the foreign key of Employee.

# Referential Integrity

Referential Integerity might be violated when a referenced tuple is

- updated, e.g., the DID 13 is changed to 16 in the Department relation.

or:

- delete, e.g., the tuple starts with DID 14 is deleted.

Three options:

- RESTRICT
- CASCADE
- SET NULL

# Example: Referential Integrity

- What will happen if:
  - We change the **DID** of Marketing to *16* in **Department**?
  - We delete the tuple for *Accounts* in **Department**?

Department

| DID | DName |
|---|---|
| 13 | Marketing |
| 14 | Accounts |
| 15 | Personnel |

Employee

| EID | EName | DID |
|---|---|---|
| 15 | John Smith | 13 |
| 16 | Mary Brown | 14 |
| 17 | Mark Jones | 13 |
| 18 | Jane Smith | NULL |

# RESTRICT

- What will happen if:
  - We change the **DID** of Marketing to *16* in **Department**?
  - We delete the tuple for *Accounts* in **Department**?
- RESTRICT stops any actions that violates referential integrity:
  - You cannot change the **DID** of *Marketing*.
  - You are not allowed to delete the tuple for *Accounts*.

Department

| DID | DName |
|---|---|
| 13 | Marketing |
| 14 | Accounts |
| 15 | Personnel |

Employee

| EID | EName | DID |
|---|---|---|
| 15 | John Smith | 13 |
| 16 | Mary Brown | 14 |
| 17 | Mark Jones | 13 |
| 18 | Jane Smith | NULL |

# CASCADE

- What will happen if:
  - We change the **DID** of Marketing to *16* in **Department**?
  - We delete the tuple for *Accounts* in **Department**?
- **CASCADE** allows the changes made to flow through:
  - The **DID** of *John Smith* and *Mark Jones* will be changed to *16*.
  - The tuple for *Mary Brown* will be deleted from **Employee**.

Department

| DID | DName |
|---|---|
| ~~13~~ 16 | Marketing |
| ~~14~~ | ~~Accounts~~ |
| 15 | Personnel |

Employee

| EID | EName | DID |
|---|---|---|
| 15 | John Smith | ~~13~~ 16 |
| ~~16~~ | ~~Mary Brown~~ | ~~14~~ |
| 17 | Mark Jones | ~~13~~ 16 |
| 18 | Jane Smith | NULL |

# SET NULL

- What will happen if:
  - We change the **DID** of Marketing to *16* in **Department**?
  - We delete the tuple for **Accounts** in **Department**?
- SET NULL allows the changes to happen, but…
  - The **DID** of *John Smith* and *Mark Jones* will be set to Null.
  - The **DID** of Mary Brown in **Employee** will be set to Null.

Department

| DID | DName |
|---|---|
| ~~13~~ 16 | Marketing |
| ~~14~~ | ~~Accounts~~ |
| 15 | Personnel |

Employee

| EID | EName | DID |
|---|---|---|
| 15 | John Smith | ~~13~~ NULL |
| 16 | Mary Brown | ~~14~~ NULL |
| 17 | Mark Jones | ~~13~~ NULL |
| 18 | Jane Smith | NULL |