## Relational Database Model

Introduced by E.F. Codd (1970)
http://www.acm.org/classics/nov95/

Based on relational algebra and logic developed by

Schröder (1880s)
Charles Peirce (1890s)
Russell and Whitehead (1900s)

## Codd's Twelve Rules

1. Information represented at the logical level in tables.
2. Data is determined by table, primary key, and column.
3. Missing information is modeled as null values.
4. Metadata is part of the database.
5. Single language for all tasks in DBMS.
6. Views and tables must change simultaneously.
7. Single operations for retrieve, insert, delete, update.
8. Operations independent of physical storage and access.
9. Database modifiable without affecting applications.
10. Constraints are part of database.
11. DML independent of physical layer (distributed, etc.)
12. Row-processing obeys same rules as set-processing.

## Relations

Extensional versus intensional

Extensional Representation:

table of values
rows = records
columns = attributes

Note: tables are ordered, relations are not

## Domains

Set of **atomic** values for an attribute

atomic = indivisible
(e.g. IT 240 = IT + 240 is divisible)

**Examples**
phone_number = {x: x is a valid phone number}
age = {x: x is a valid age}

Physical Level: data type + format

## Relation Schema

$R(A_1, A_2, \ldots, A_n)$ **relational schema**

R : Name of Relation
$A_1, A_2, \ldots, A_n$ : **Attributes** $A_i$ has **domain** $D_i$
N : **degree** (**arity**) of R

Movie(movieID, title, genre, length, rating)

dom(movieID) = MovieIDs = {x: x is a number}
dom(title) = Titles = {x: x is a word}
dom(genre) = Genres = {Musical, Horror, …}
dom(length) = Lengths = {x: x is valid time}
dom(rating) = Ratings = {PG, R, PG-13, NC-17, …}

## Relational Schemas Example

CUSTOMER(Customer_ID, Customer_Name, City, State, Postal_Code)
ORDER(Order_ID, Order_Date, Customer_ID)
ORDERLINE(Order_ID, Product_ID, Ordered_Quantity)
PRODUCT(Product_ID, Product_Description, Product_Finish, Standard_Price, Product_Line_ID)

Figure 5-3, page 191

## Instances

$R(A_1, A_2, \ldots, A_n)$ **relational schema,**
$A_i$ has **domain** $D_i$

**Instance** of schema R is a table with data from domains

**Example:**

Figure 5-4, page 192 (tables)
Table 5-1, page 193 (domains)

## Schema and Relation Examples

STUDENT(Name, SSN, HomePhone, Address,
OfficePhone, Age, GPA)

MOVIE

VIDEO

RENTAL

## Records

<101, "Thirty-Nine Steps", mystery, 101, R>
<510, "Monkey Business", comedy, null, null>

are possible **records (or tuples)** in

MOVIE(movieID, title, genre, length, rating).

**null**: value unknown, or attribute does not apply
values **atomic**: no multiple values (first normal form)
(e.g. several genres)
indivisible (name = first name + last name

## What about multiple values?

**Example**

Telephone numbers

Figure 5-2, page 190

## Functional Dependencies I

ORDER_DETAIL(Product, Quantity, PricePerUnit, Subtotal)

**Example**

<Soymilk, 3, $3.19, $9.57> in ORDER_DETAIL

(Quantity, PricePerUnit) → Subtotal

Quantity and PricePerUnit determine Subtotal

## Functional Dependencies II

A → B (A determines B)

if

setting the values of attribute(s) of A determines the values of B

**Example:**

SSN → Name in STUDENT(SSN, Name)

## Functional Dependencies III

EMPLOYEE(EmpID, FirstName, LastName, Salary, Sex)

STUDENT(Name, SSN, HomePhone, Address, OfficePhone, Age, GPA)

PRODUCT(ProductID, Name, Description, PricePerUnit, UnitSize)

CAR(OwnerName, Vehicle#, Engine#, Color)

CUSTOMER(accountID, lastName, firstName, street, city, state, zipcode)

## Constraints

- Domain constraints
- Key (uniqueness) constraints
- Entity integrity constraints
- Referential integrity constraints

- Data dependencies (functional dependencies, etc.)

## Domain Constraints

Restriction on values of attributes (domain).

Specified as **data-type:** integer, char, etc., or user-defined type

Operations on data-types: +, *, <, =, …

**not null** constraint for an attribute

## Keys

**Key**: smallest set of attributes that determines all attributes in a relation.
if key has more than one attribute, it is called **composite**

**Example**
STUDENT(Name, SSN, HomePhone, Address, OfficePhone, Age, GPA)

{SSN}: key
{SSN, Name, Address}: not key

## Key Examples

MOVIE(Title, Year, Director, Length, Rating)

PRODUCT(ProductID, Name, Description, PricePerUnit, UnitSize)

ACTIVITY(StudentID, Activity, Fee)

COURSE(CourseID, Title, Enrolment)

ENROLED(StudentID, CourseID, CourseTitle, Grade)

## Candidate Keys

If a relation has more than one key, these keys are called **candidate keys**.

**Examples**
- EMPLOYEE(EmpID, FirstName, LastName, Salary, Gender)
- DePaul students: peoplesoftID and SSN
- COURSE(Department, Number, Name, Instructor)
- CAR(OwnerName, Vehicle#, Engine#, Color)

One candidate key is declared the **primary key** of the relation (underlined in schema)

# Relational Databases and Schemas

Relational Database **Schema**: Collection of Relations
Relational Database **State**: Collection of Instances

ACTIVITIES = {STUDENT, ACTIVITY}

| Student | SID | FName | LName |
|---|---|---|---|
| | 101 | Mark | Spencer |
| | 971 | Charles | Loeffler |

| Activity | StudentID | Activity | Fee |
|---|---|---|---|
| | 971 | Piano | $20 |
| | 971 | Swimming | $10 |

**Note**: different names (SID, StudentID) for the same concepts

# Foreign Key 1

A set of attributes in one relation ($R_1$ ) refering to a unique tuple in a second relation ($R_2$) through $R_2$'s primary key.

| Student | SID | FName | LName |
|---|---|---|---|
| | 101 | Mark | Spencer |
| | 353 | Gil | Ryle |
| | 971 | Charles | Loeffler |

| Activity | StudentID | Activity | Fee |
|---|---|---|---|
| | 971 | Piano | $20 |
| | 353 | Reading | $5 |
| | 971 | Swimming | $10 |

Terminology $R_1$ referencing relation
$R_2$ referenced relation

# Foreign Key 2

**Examples**

REGISTRATION = {STUDENT, ENROLMENT, COURSE}
COMPANY = {EMPLOYEE, WORKS_ON, PROJECT}
SUPPLY = {SUPPLIES, SUPPLIER, PART, COMPANY}

**Note** R1 = R2 is possible

**Example**

EMPLOYEE (with supervisor)

MOVIE (remakes)

## Referential Integrity

declaration of foreign keys in a database schema

STUDENT(SID, FName, LName)
ACTIVITIES(StudentID references STUDENT, Activity, Fee)

or visually, by an arrow from foreign key to primary key

STUDENT(SID, FName, LName)

ACTIVITIES(StudentID, Activity, Fee)

## Integrity Constraints

- **Domain Constraints:** declaration of domains
- **Not Null Constraints:** attribute values can not be null
- **Key Constraints:** candidate keys (uniqueness)
- **Entity Integrity Constraint**: primary key is not null
- **Referential Integrity Constraint:** declaring foreign keys

A **valid state** is a database state fulfilling all integrity constraints

Integrity Constraints defined by DDL

Semantic constraints (transitions) later