Databases - Relational Model

Goals

- Understand:
  - The relational model
  - Relational model terminology
- Write SQL statements to create tables
Why Study the Relational Model?

- Most widely used model.
  - Vendors: IBM, Microsoft, Oracle, Sybase, etc.
- Competitors:
  - Key-value stores, NoSQL
  - Object-Oriented model
    - ObjectStore, Versant, Ontos
  - A synthesis: *object-relational model*
    - Informix Universal Server, Oracle, DB2
  - XML
Relational Database

- A relation is a two-dimensional table
- Relation schema describes the structure for the table
  - Relation name
  - Column names
  - Column types
- A relational database is a set of relations

Relation Example

EMPLOYEE(EmployeeNumber:integer, FirstName:string, LastName:string, Department:string, Email:string, Phone:integer)

<table>
<thead>
<tr>
<th>EmployeeNumber</th>
<th>FirstName</th>
<th>LastName</th>
<th>Department</th>
<th>Email</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Jerry</td>
<td>Johnson</td>
<td>Accounting</td>
<td><a href="mailto:JJ@somewhere.com">JJ@somewhere.com</a></td>
<td>236-9987</td>
</tr>
<tr>
<td>200</td>
<td>Mary</td>
<td>Abemathy</td>
<td>Finance</td>
<td><a href="mailto:MA@somewhere.com">MA@somewhere.com</a></td>
<td>444-8898</td>
</tr>
<tr>
<td>300</td>
<td>Liz</td>
<td>Smathers</td>
<td>Finance</td>
<td><a href="mailto:LS@somewhere.com">LS@somewhere.com</a></td>
<td>777-0098</td>
</tr>
<tr>
<td>400</td>
<td>Tom</td>
<td>Caruthers</td>
<td>Accounting</td>
<td><a href="mailto:TC@somewhere.com">TC@somewhere.com</a></td>
<td>236-9987</td>
</tr>
<tr>
<td>500</td>
<td>Tom</td>
<td>Jackson</td>
<td>Production</td>
<td><a href="mailto:TJ@somewhere.com">TJ@somewhere.com</a></td>
<td>444-9980</td>
</tr>
<tr>
<td>600</td>
<td>Eleanore</td>
<td>Caldera</td>
<td>Legal</td>
<td><a href="mailto:EC@somewhere.com">EC@somewhere.com</a></td>
<td>767-0900</td>
</tr>
<tr>
<td>700</td>
<td>Richard</td>
<td>Bandalone</td>
<td>Legal</td>
<td><a href="mailto:RB@somewhere.com">RB@somewhere.com</a></td>
<td>767-0900</td>
</tr>
</tbody>
</table>
Relation

- All entries in a column are of the same kind
- Each column has a unique name
- Cells of the table hold a single value
- The order of the columns is not important
- The order of the rows is not important
- No two rows may be identical

Tables That Are Not Relations

<table>
<thead>
<tr>
<th>EmployeeNumber</th>
<th>FirstName</th>
<th>LastName</th>
<th>Department</th>
<th>Email</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Jerry</td>
<td>Johnson</td>
<td>Accounting</td>
<td><a href="mailto:Jerry@somewhere.com">Jerry@somewhere.com</a></td>
<td>236-0300</td>
</tr>
<tr>
<td>200</td>
<td>Mary</td>
<td>Abernathy</td>
<td>Finance</td>
<td><a href="mailto:Mary@somewhere.com">Mary@somewhere.com</a></td>
<td>444-8996</td>
</tr>
<tr>
<td>300</td>
<td>Liz</td>
<td>Smathers</td>
<td>Finance</td>
<td><a href="mailto:LS@somewhere.com">LS@somewhere.com</a></td>
<td>722-0000</td>
</tr>
<tr>
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<td>Tom</td>
<td>Canuthers</td>
<td>Accounting</td>
<td><a href="mailto:TC@somewhere.com">TC@somewhere.com</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>236-0991, 236-0993</td>
</tr>
<tr>
<td>500</td>
<td>Tom</td>
<td>Jackson</td>
<td>Production</td>
<td><a href="mailto:TJ@somewhere.com">TJ@somewhere.com</a></td>
<td>444-9989</td>
</tr>
<tr>
<td>600</td>
<td>Eleanor</td>
<td>Caldera</td>
<td>Legal</td>
<td><a href="mailto:EC@somewhere.com">EC@somewhere.com</a></td>
<td>767-0900</td>
</tr>
<tr>
<td>700</td>
<td>Richard</td>
<td>Bandalene</td>
<td>Legal</td>
<td><a href="mailto:RB@somewhere.com">RB@somewhere.com</a></td>
<td>767-0900, 767-0911</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EmployeeNumber</th>
<th>FirstName</th>
<th>LastName</th>
<th>Department</th>
<th>Email</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
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<td>767-0900</td>
</tr>
</tbody>
</table>

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Home: 566-7171
Alternative Terminology

- Although not all tables are relations, the terms table and relation are normally used interchangeably.
- The following sets of terms are used interchangeably:

<table>
<thead>
<tr>
<th>Table</th>
<th>Column</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relation</td>
<td>Attribute</td>
<td>Tuple</td>
</tr>
<tr>
<td>File</td>
<td>Field</td>
<td>Record</td>
</tr>
</tbody>
</table>

ICE: Is This a Relation? Why?

<table>
<thead>
<tr>
<th>A</th>
<th>X</th>
<th>C</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>John</td>
<td>Ryan</td>
<td>MD</td>
<td><a href="mailto:jr@gmail.com">jr@gmail.com</a></td>
</tr>
<tr>
<td>Bob</td>
<td>Smith</td>
<td>MD, VA, NY</td>
<td><a href="mailto:bsm@gmail.com">bsm@gmail.com</a></td>
</tr>
<tr>
<td>Alice</td>
<td>Brown</td>
<td>CA</td>
<td></td>
</tr>
<tr>
<td>Jane</td>
<td>Doe</td>
<td>WA</td>
<td><a href="mailto:jd@yahoo.com">jd@yahoo.com</a></td>
</tr>
<tr>
<td>John</td>
<td>Ryan</td>
<td>MD</td>
<td><a href="mailto:jr@gmail.com">jr@gmail.com</a></td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>
Create a Table

- **CREATE TABLE** statement is used for creating relations/tables
- Each column is described with three parts:
  - column name
  - data type
  - optional constraints

### Specify Data Types

- Choose the most specific data type possible!!!
- Generic Data Types:
  - CHAR(n)
  - VARCHAR(n)
  - DATE
  - TIME
  - MONEY
  - INTEGER
  - DECIMAL

```sql
CREATE TABLE EMPLOYEE (
    EmployeeNumber integer,
    EmployeeName char(50),
    Phone char(15),
    Email char(50),
    HireDate date,
    ReviewDate date
)
```
Specify Null Status

- **Null status**: whether or not the value of the column can be NULL

```sql
CREATE TABLE EMPLOYEE (  
  EmployeeNumber integer NOT NULL,  
  EmployeeName char (50) NOT NULL,  
  Phone char (15) NULL,  
  Email char(50) NULL,  
  HireDate date NOT NULL,  
  ReviewDate date NULL
)
```

Specify Default Values

- **Default value** - value supplied by the DBMS, if no value is specified when a row is inserted

```sql
CREATE TABLE EMPLOYEE (  
  EmployeeNumber integer NOT NULL,  
  EmployeeName char (50) NOT NULL,  
  Phone char (15) NULL,  
  Email char(50) NULL,  
  HireDate date NOT NULL DEFAULT (getdate()),  
  ReviewDate date NULL
)
```
Specify Other Data Constraints

- **Data constraints** are limitations on data values

```sql
CREATE TABLE EMPLOYEE (  
    EmployeeNumber integer NOT NULL,  
    EmployeeName char (50) NOT NULL,  
    Phone char (15) NULL,  
    Email char(50) NULL,  
    HireDate date NOT NULL DEFAULT (getdate()),  
    ReviewDate date NULL,  
    CONSTRAINT Check_Email CHECK (Email LIKE '%@gmail.com')
)  
```

Integrity Constraints (IC)

- **IC**: condition that must be true for any instance of the database
  - Domain constraints
  - Key constraints
  - Foreign Key constraints
- ICs are **specified** when schema is defined
- ICs are **checked** when relations are modified
- A legal instance of a relation is one that satisfies all specified ICs
  - DBMS should not allow illegal instances
Keys

- A **key** is a combination of one or more columns that is used to identify rows in a relation
- A **composite key** is a key that consists of two or more columns
- A set of columns is a **key** for a relation if:
  1. No two distinct rows can have same values in all key columns, and
  2. This is not true for any subset of the key
- Part 2 false? A **superkey**

Candidate and Primary Keys

- A **candidate key** is a key
- A **primary key** is a candidate key selected as the primary means of identifying rows in a relation:
  - There is one and only one primary key per relation
  - The primary key may be a composite key
  - The ideal primary key is short, numeric and never changes
Surrogate Keys

- A **surrogate key** is an artificial column added to a relation to serve as a primary key:
  - DBMS supplied
  - Short, numeric and never changes – an ideal primary key!
  - Has artificial values that are meaningless to users
- MS Access (ID – auto number)
- MySQL - autoincrement

Specify Primary Key

```sql
CREATE TABLE EMPLOYEE (  
    EmployeeNumber integer NOT NULL,  
    EmployeeName char (50) NOT NULL,  
    Phone char (15) NULL,  
    Email char(50) NULL,  
    HireDate date NOT NULL DEFAULT (getdate()),  
    ReviewDate date NULL,  
    CONSTRAINT Check_Email CHECK (Email LIKE '%@gmail.com'),  
    CONSTRAINT PK_Employee PRIMARY KEY (EmployeeNumber)  
)
```
Specify Alternate Keys

- **Alternate keys**: alternate identifiers of unique rows in a table

```sql
CREATE TABLE EMPLOYEE (  
    EmployeeNumber integer NOT NULL,  
    EmployeeName char (50) NOT NULL,  
    Phone char (15) NULL,  
    Email char (50) NULL,  
    HireDate date NOT NULL DEFAULT (getdate()),  
    ReviewDate date NULL,  
    CONSTRAINT Check_Email CHECK (Email LIKE '%@gmail.com'),  
    CONSTRAINT PK_Employee PRIMARY KEY (EmployeeNumber),  
    CONSTRAINT AK_Email UNIQUE (Email),  
    CONSTRAINT AK_ENamePhone UNIQUE (EmployeeName, Phone)
)
```

ICE: Find possible PK, AK

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Y</td>
<td>Z</td>
<td>W</td>
</tr>
<tr>
<td>John</td>
<td>Ryan</td>
<td>MD</td>
<td><a href="mailto:jr@gmail.com">jr@gmail.com</a></td>
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<tr>
<td>Bob</td>
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<tr>
<td>John</td>
<td>Doe</td>
<td>WA</td>
<td><a href="mailto:jd@yahoo.com">jd@yahoo.com</a></td>
</tr>
</tbody>
</table>
Foreign Keys and Referential Integrity Constraints

- A **foreign key** is the primary key of one relation that is placed in another relation to form a link between the relations.

- A **referential integrity constraint**: the values of the foreign key must exist as primary key values in the corresponding relation → No ‘dangling references’

Foreign Keys

```sql
CREATE TABLE LOCKER(
    LockerNumber integer PRIMARY KEY,
    LockerRoom integer,
    LockerSize integer)

CREATE TABLE CLUB_MEMBER(
    MemberNumber integer PRIMARY KEY,
    MemberName char(50),
    Phone char(15),
    Email char(50),
    LockerNumber integer NULL,
    CONSTRAINT FK_Locker FOREIGN KEY (LockerNumber) REFERENCES LOCKER(LockerNumber),
    CONSTRAINT Unique_Locker UNIQUE(LockerNumber))
```
Enforcing Referential Integrity

- What if a new “Member” row is added/updated that references a non-existent locker?
  - Reject it!
- What if a Locker row is deleted? Options:
  - Also delete all Member rows that refer to it.
  - Disallow deletion of Locker row that is referred.
  - Set \textit{LockerNumber} in Member to default value
  - Set \textit{LockerNumber} in Member to \textit{null}
- Similar if primary key of Locker row is updated

Referential Integrity in SQL/92

- SQL/92 supports all 4 options on deletes and updates.
  - Default is \text{NO ACTION} (\textit{delete/update is rejected})
  - \text{CASCADE} (\textit{delete/update all rows that refer to deleted/updated row})
  - \text{SET NULL / SET DEFAULT}

```sql
CREATE TABLE CLUB_MEMBER(  
    MemberNumber integer PRIMARY KEY  
    MemberName char(50),  
    Phone char(15),  
    Email char(50),  
    LockerNumber integer NULL,  
    CONSTRAINT FK_Locker FOREIGN KEY (LockerNumber) REFERENCES LOCKER(LockerNumber) ON DELETE SET NULL ON UPDATE CASCADE,  
    CONSTRAINT Unique_Locker UNIQUE(LockerNumber))
```
FOREIGN KEY Constraints

CREATE TABLE Departments
    (DepartmentName char(18),
     Phone char(18) NOT NULL,
     Building char(18),
     Room integer,
     PRIMARY KEY (DepartmentName)
    )

Summary – Relational Model

- 2-D tables
- Relational schema: structure of table
- Constraints
  - Domain
  - Key
    - Candidate, Primary, Alternate, Surrogate
    - Foreign key – Referential integrity constraint
SQL: Creating Tables

```
CREATE TABLE table_name(
    column_name1 column_type1 [constraints1],
    ...
    [CONSTRAINT constraint_name] table_constraint
)
```

Table constraints:
- NULL/NOT NULL
- PRIMARY KEY (columns)
- UNIQUE (columns)
- CHECK (conditions)
- FOREIGN KEY (local_columns) REFERENCES foreign_table (foreign_columns) [ON DELETE action_d ON UPDATE action_u]

Specify surrogate key in MySQL:
```
column_name int_type AUTO_INCREMENT
```