Designing Tables Is Not Easy

Entity-Relationship (ER) Model

Problem → ER Model → Tables

- An object-oriented approach
- A visual representation of the design – ER Diagram
- Easily converted to relational model

Example: Problem Description

- Student
  - id, name, address
- Department
  - name
- Classes
  - code, name, quarter, section number
- Class offerings and enrollment

Example: ER Diagram

Entity Set and Attributes

- Entity Set is similar to class in an OO language
- Attributes are the properties of an entity set
- Similar to the class fields in an OO language
- Must have simple values like numbers or strings, i.e., cannot be collection or composite type
Keys

- A key is an attribute or a set of attributes that uniquely identify an entity in an entity set.
- Each entity set must have a key.
- If there are multiple keys, choose one of them as the primary key.

Types of Relationships

- Many-to-Many
- Many-to-One / One-to-Many
- One-to-One

Many-to-Many Relationship

- Each entity in E₁ can be related to many entities in E₂.
- Each entity in E₂ can be related to many entities in E₁.

Many-to-One Relationship

- Each entity in E₁ can be related to one entity in E₂.
- Each entity in E₂ can be related to many entities in E₁.

One-to-One Relationship

- Each entity in E₁ can be related to one entity in E₂.
- Each entity in E₂ can be related to one entity in E₁.

Relationship Type Examples

- Students and classes??
- Departments and classes??
- Person and Favorite movie??
Relationship Types in ER Diagram

- **An arrow is used to indicate the "one" side**

Referential Integrity in ER Diagram

- **An circular arrow is used to indicate "Exactly 1"**

Example: Grades

- **Store the grades the students received for their classes**
- **A grade is a single letter A, B, C, D, or F**

Relationship Attributes ...

- **Sometimes it’s useful to attach an attribute to a relationship.**
... Relationship Attributes ...

Some variations of ER model do not allow relationships to have attributes

Example: More about Grades

Make Grades an entity set

“Arrows” in Multiway Relationships

In multiway relationships, an arrow points to an entity set E means that if we select one entity from each of the other entity sets in the relationship, those entities are related to at most one entity in E.
Example: Employees and Supervisors

- Each employee has a supervisor
- A supervisor is an employee

Roles

- An entity set may appear in the same relationship more than once.
- Label the edges with names called Roles

Example: Players and Teams

- What's the key for Players??

Weak Entity Set

- Entity set \( E \) is said to be weak if in order to identify entities of \( E \) uniquely, we need to follow one or more many-one relationships from \( E \) and include the key of the related entities from the connected entity sets.

Weak Entity Sets in ER Diagram

- The key of a weak entity set consists of its own key attributes and the key attributes of the supporting set

From Weak to Strong

- We can usually create unique IDs for entity sets
Subclass

Summary of ER Diagram

- **Entity Set**
  - Attributes, key
  - Weak entity set

- **Relationship**
  - Many-to-Many, Many-to-One, One-to-One
  - Attributes
  - Multiway relationship
  - Subclass

Relational Model

- Proposed by Edgar F. Codd in early 1970's
- Data is stored in tables (a.k.a. relations)
- All major database systems these day are relational

<table>
<thead>
<tr>
<th>student_id</th>
<th>first_name</th>
<th>last_name</th>
<th>birthday</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000001</td>
<td>John</td>
<td>Doe</td>
<td>1970-1-1</td>
</tr>
<tr>
<td>2000002</td>
<td>Jane</td>
<td>Doe</td>
<td>1971-1-1</td>
</tr>
<tr>
<td>2000003</td>
<td>Tom</td>
<td>Smith</td>
<td>1962-2-2</td>
</tr>
</tbody>
</table>

About Relational Model

- Attributes must be of simple type
- No order among attributes
- No order among records

Table (Relation)

<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>John</td>
</tr>
<tr>
<td>1001</td>
<td>Jane</td>
</tr>
</tbody>
</table>

Table and Database Schema

- Table schema
  - Name of the table, and the names and types of the attributes
  - E.g. `students(id:integer, name:string)` or just `students(id, name)`

- Database schema
  - Schemas of all the tables in the database
Basic Rules of ER to Relational Conversion

- A entity set is converted to a table.
- A many-to-many relationship is also converted to a table, including:
  - Its own attributes.
  - Key attributes from the associated entity sets.
- A many-to-one relationship is merged into the “many” side with a foreign key to the “one” side.

Conversion Example: ER Diagram

Conversion Example: Relational Schema

Students( id, name, address )
Departments( name )
Classes( code, name, quarter, section, department_name )
Takes( student_id, code, quarter, section )

More Conversion Examples

Converting One-to-One Relationship ...
... Converting One-to-One Relationship

Which one of the following makes more sense??

- Faculty( id, name, chair_of_department )
  Departments( id, name )

- Faculty( id, name )
  Departments( id, name, department_chair )

Converting Multiway Relationship

Should this relationship be treated as many-to-many or many-to-one??

Converting Weak Entity Set ...

- The table for a weak entity set includes its complete key as well as its own non-key attributes
- A supporting relationship is redundant and yields no relation

Converting Subclass ...

Object-oriented approach
- One table per class
- Each entity belongs to exact one table

ER approach
- One table per class
- Each entity may appear in multiple tables

NULL approach
- One table per class hierarchy
Object-Oriented Approach

<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>John</td>
</tr>
</tbody>
</table>

Users

<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
<th>cin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1001</td>
<td>Jane</td>
<td>212345678</td>
</tr>
</tbody>
</table>

Students

ER Approach

<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>John</td>
</tr>
<tr>
<td>1001</td>
<td>Jane</td>
</tr>
</tbody>
</table>

Users

<table>
<thead>
<tr>
<th>user_id</th>
<th>cin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1001</td>
<td>212345678</td>
</tr>
</tbody>
</table>

Students

NULL Approach ...

<table>
<thead>
<tr>
<th>id</th>
<th>name</th>
<th>cin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>John</td>
<td>NULL</td>
</tr>
<tr>
<td>1001</td>
<td>Jane</td>
<td>212345678</td>
</tr>
</tbody>
</table>

Users

... NULL Approach

Discriminator field

<table>
<thead>
<tr>
<th>id</th>
<th>user_type</th>
<th>name</th>
<th>cin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>staff</td>
<td>John</td>
<td>NULL</td>
</tr>
<tr>
<td>1001</td>
<td>student</td>
<td>Jane</td>
<td>212345678</td>
</tr>
</tbody>
</table>

Users

Comparison of Subclass Conversion Approaches

- Constraints and data integrity
- Query performance

Q1: find the number of users
Q2: find the number of students

Summary of ER to Relational Conversion

- Basic rules
  - Entity set
  - Many-to-many relationship
  - Many-to-one relationship
- Special cases
  - One-to-one relationship
  - Multiway relationship
  - Weak entity set
  - Subclass
Common Problems in ER Diagram

- Student_id
- Code
- Name
- Take
- Offer
- Class_id
- Id
- Code
- Department_id

Common Mistakes of ER Design

- ER diagram
  - Missing arrows
  - Missing keys
  - Redundant foreign keys
- ER to relational conversion
  - Missing tables for many-to-many relationships

Variations of ER Model

- Rule differences
  - Relationships cannot have attributes
  - Anything that has attributes should be an entity set
  - No multiway relationship
- Notational differences
  - Classic ER diagram
  - OO style ER diagram

Classic ER Diagram

- Highlight the three distinct components of the ER model
- Allow relationship attributes and multiway relationships
- Difficult to draw
- Can look messy even for a relatively simple schema

OO Style ER Diagram

- Easier to draw, especially using class/table design tools
- Looks cleaner
- No relationship attributes
- No multiway relationships

Design Example 1: Restaurant

- Design Example 2
- Some Restaurant
- Date: Jul 09, 2008
- Time: 03:17PM
- Server: John
- No of Guest: 2
- Bill: $98.00
- Subtotal: $97.00
- Tax: $1.00
- Total: $98.00
- Open Time: Jul 09, 2008 02:57PM
- Printed by: Cashier
Design Example 2: Folders and Files

Design Example 3: Price That Changes

What if we want to model price that changes??