The Entity-Relationship (ER) Model

(Study Cow book Chapter 2)
Overview of Database Design

- **Conceptual design**: (ER Model is used at this stage.)
  - What are the *entities* and *relationships* in the enterprise?
  - What information about these entities and relationships should we store in the database?
  - What are the *integrity constraints* or *business rules* that hold?
  - A database “schema” in the ER Model are represented pictorially (ER diagrams).
  - Can map an ER diagram into a relational schema.
ER Modeling and ER Diagrams

- **Entity**: An object distinguishable from other objects. Entities are characterized by a set of attributes.

- **Entity Set**: A collection of similar entities. E.g., all employees.
  - All entities in an entity set have the same set of attributes. (Until we consider ISA hierarchies, anyway!)
  - Each entity set has a key.
  - Each attribute has a domain.

```
Entity
  attrib_1
  attrib_2
  ... 
  attrib_n

Employees
  ssn
  name
  lot

entity
```
**ER Model Basics**

- **Relationship**: Association among two or more entities. e.g., David works in the Math department.

- **Relationship Set**: Collection of similar relationships.
  - An n-ary relationship set \( R \) relates \( n \) entity sets \( E_1 \ldots E_n \); each relationship in \( R \) involves entities \( \{(e_1, \ldots, e_n) | e_1 \in E_1, \ldots, e_n \in E_n \} \).  
  - Same entity set could participate in different relationship sets, or in different “roles” in same set.
Key Constraints

- Consider Works_In: An employee can work in many departments; a dept can have many employees.

- In contrast, each dept has at most one manager, according to the key constraint on Manages.
Participation Constraints

- Do all departments have exactly one manager?
  - If so, this is a *participation constraint*: the participation of Departments in Manages is said to be *total* *(vs. partial).*
  - Every Departments entity must appear in an instance of the Manages relationship, which relates each department to the employee who manages it.
A weak entity can be identified uniquely only by considering the primary key of another (owner) entity.

- Owner entity set and weak entity set must participate in a one-to-many relationship set (one owner, many weak entities).
- Weak entity set must have total participation in this identifying relationship set.
ISA (‘is a’) Hierarchies

- It is often useful to subdivide entities into classes, like in an OOL.
- If we declare A ISA B, every A entity is also considered to be a B entity.

- **Overlap constraints**: Can Joe be an Hourly_Emps as well as a Contract_Emps entity? *(Allowed/disallowed)*
- **Covering constraints**: Does every Employees entity also have to be an Hourly_Emps or a Contract_Emps entity? *(Yes/no)*
- Reasons for using ISA:
  - To add descriptive attributes specific to a subclass.
  - To identify entities that participate in a relationship.
Aggregation

- Used when we have to model a relationship involving (entity sets and) a relationship set.
  - **Aggregation** allows a relationship set to be treated as an entity set for purposes of participation in (other) relationships.

**Aggregation vs. ternary relationship:**
- Monitors is a distinct relationship, with a descriptive attribute.
- Each sponsorship is monitored by at most one employee.
Conceptual Design Using the ER Model

- **Design choices:**
  - Should a concept be modeled as an entity or an attribute?
  - Should a concept be modeled as an entity or a relationship?
  - Identifying relationships: Binary or ternary? Aggregation?

- **Constraints in the ER Model:**
  - A lot of data semantics can (and should) be captured.
  - But some constraints cannot be captured in ER diagrams.
Entity vs. Attribute

- Should *address* be an attribute of Employees or an entity (connected to Employees by a relationship)?
- Depends upon the use we want to make of address information, and the semantics of the data:
  - If we have several addresses per employee, *address* must be an entity (since attributes cannot themselves be sets (multivalued)).
  - If the structure (city, street, etc.) is important, e.g., we want to retrieve employees in a given city, *address* must be modeled as an entity (since attribute values are atomic).
Entity vs. Attribute (Contd.)

- Works_In4 does not allow an employee to work in a department for two or more periods.

- Similar to the problem of wanting to record several addresses for an employee: We want to record several values of the descriptive attributes for each instance of this relationship. Accomplished by introducing a new entity set, Duration.
Entity vs. Relationship

- First ER diagram OK if a manager gets a separate discretionary budget for each dept.

- What if a manager gets a discretionary budget that covers all managed depts?
  - **Redundancy**: $dbudget$ stored for each dept managed by manager.
  - **Misleading**: Suggests $dbudget$ associated with department-mgr combination.

This fixes the problem!
Binary vs. Ternary Relationships

- If each policy is owned by just 1 employee, and each dependent is tied to the covering policy, the first diagram is inaccurate.

- What are the additional constraints in the 2nd diagram?

Better design
Binary vs. Ternary Relationships (Contd.)

- Previous example illustrated a case when two binary relationships were better than one ternary relationship.

- An example in the other direction: a ternary relation **Contracts** relates entity sets **Parts, Departments** and **Suppliers**, and has descriptive attribute $qty$. No combination of binary relationships is an adequate substitute:
  - S “can-supply” P, D “needs” P, and D “deals-with” S does not imply that D has agreed to buy P from S.
  - Where do we record $qty$?
Summary of Conceptual Design

- Conceptual design follows requirements analysis,
  - Yields a high-level description of data to be stored
- ER model popular for conceptual design
  - Constructs are expressive, close to the way people think about their applications.
- Basic constructs: entities, relationships, and attributes (of entities and relationships).
- Some additional constructs: weak entities, ISA hierarchies, and aggregation.
- Note: There are many variations on ER model.
Several kinds of integrity constraints can be expressed in the ER model: *key constraints*, *participation constraints*, and *overlap/covering constraints* for ISA hierarchies. Some *foreign key constraints* are also implicit in the definition of a relationship set.

- Some constraints (notably, *functional dependencies*) cannot be expressed in the ER model.
- Constraints play an important role in determining the best database design for an enterprise.
Summary of ER (Contd.)

- ER design is *subjective*. There are often many ways to model a given scenario! Analyzing alternatives can be tricky, especially for a large enterprise. Common choices include:
  - Entity vs. attribute, entity vs. relationship, binary or n-ary relationship, whether or not to use ISA hierarchies, and whether or not to use aggregation.

- Ensuring good database design: resulting relational schema should be analyzed and refined further. FD information and normalization techniques are especially useful.
Next Time

- The Relational Model