Chapter 2
Conceptual Modeling

Entity Relationship Diagrams

Objectives

• Definition of terms
• Importance of data modeling
• Write good names and definitions for entities, relationships, and attributes
• Distinguish unary, binary, and ternary relationships
• Model different types of attributes, entities, relationships, and cardinalities
• Draw E-R diagrams for common business situations
• Convert many-to-many relationships to associative entities
• Model time-dependent data using time stamps
**Business Rules**

- Statements that define or constrain some aspect of the business
- Assert business structure
- Control/influence business behavior
- Are expressed in terms familiar to end users
- Govern how data are stored and handled.
- Our DB App will (hopefully) automate business rules

**E/R Modeling**

- The E/R model is used to construct a conceptual data model – a representation of the structure and constraints of a database and is the technology independent.
E-R Modeling

- An E-R model is based on:
  - Entities
  - Relationships between entities
  - Attributes of entities and relationships

- E-R diagram
  - a graphical representation of an E-R model

Sample E-R Diagram (Figure 2-1)
Basic E-R notation (Figure 2-2)

Entity symbols

A special entity that is also a relationship

Relationship degrees specify number of entity types involved

Attribute symbols

Relationship symbols

Relationship cardinalities specify how many of each entity type is allowed

Modeling Business Rules

• Business rules
  – Statements that define the business.
  – Expressed in natural language for end users
  – Expressed in data models for system developers

• A Good Business Rule is: (Table 2-1)
  – **Declarative** – what, not how
  – **Precise** – clear, agreed-upon meaning
  – **Atomic** – one statement
  – **Consistent** – internally and externally
  – **Expressible** – structured, natural language
  – **Distinct** – non-redundant
  – **Business-oriented** – understood by business people
A Good Data Name is:

- Related to business, not technical
- Meaningful and self-documenting
- Unique
- Readable
- Composed of words from an approved list
- Repeatable
- Written in standard syntax

Modeling Entities and Attributes
Entities

• Things in the real world, physical or not: person, place, object, event, concept

• Entity Type
  – collection of entities that share properties or characteristics
  – Entity type is always SINGULAR
  – Represented by a rectangle

• Entity Instance
  – each of the instances of an entity type

What Should an Entity Be?

• SHOULD BE:
  – An object that we are trying to model
  – An object that will have many instances in the database

• SHOULD NOT BE:
  – A user of the database system
  – An output of the database system (e.g. a report)
Attributes

- Attribute - property or characteristic of an entity type that is of interest to the organization.
- Classifications of attributes:
  - Required versus Optional Attributes
  - Simple versus Composite Attribute
  - Single-Valued versus Multi-valued Attribute
  - Stored versus Derived Attributes
  - Identifier Attributes
Figure 2-7 A composite attribute

An attribute broken into component parts

Figure 2-8 Entity with multivalued attribute (Skill) and derived attribute (Years Employed)

Multivalued an employee can have more than one skill

Derived from date employed and current date

Identifiers (Keys)

• Identifier (Key) - An attribute (or combination of attributes) that uniquely identifies individual instances of an entity type
• Simple Key versus Composite Key
• Candidate Key – an attribute that could be a key…satisfies the requirements for being a key
Criteria for Selecting Identifiers

- Will not change in value over the life of each instance of the entity type.
- Will not be NULL.
- No intelligent identifiers (containing e.g., locations or people that might change)
- Substitute new, simple (e.g., surrogate attribute) keys for long, composite keys (e.g., entity type of Game: Game# instead of Home_Team and Visitor_Team)

Figure 2-9 Simple and composite identifier attributes
Practice: Person

- Produce an E-R diagram for the following situation:

We have one entity, called Person, with the following attributes: ID (the identifier); Name, which is composed of one or more given names and one or more family names; one or more aliases; an address (composed of street, city, state, zip); date of birth; and age, which can be calculated from the date of birth.

![E-R Diagram](image)

Relationships

- Association between two or more entities
- Represented by connecting lines

![Diagram with relationships](image)
Figure 2-10 Relationship types and instances

a) Relationship type (Completes)

b) Relationship instances

Relationships

- Degree
- Cardinality constraints
Degree of relationships – from Figure 2-2

Fig. 2-12: (b) Binary relationships
Interpreting Cardinalities

STUDENT

Majors in

PROGRAM

Interpreting Cardinalities

STUDENT

Majors in

PROGRAM
Cardinality Constraints

- Cardinality Constraints - the number of instances of one entity that can or must be associated with each instance of another entity.
  - Minimum Cardinality
    - If zero, then optional
    - If one or more, then mandatory
  - Maximum Cardinality
    - The maximum number

Quick Check

- So now you try it. Add cardinality constraints to the following diagram
  - A person is national of zero or more countries
  - A country has one or more people.
Fig. 2-16: Introducing cardinality constraint
(a) Basic relationship

![Diagram of basic relationship between MOVIE and DVD]

(a) Relationship with cardinality constraints

![Diagram showing relationship with cardinality constraints between MOVIE and DVD]

Figure 2-17 Examples of cardinality constraints

**a) Mandatory cardinalities**

A patient history is recorded for one and only one patient

A patient must have recorded at least one history, and can have many
Figure 2-17 Examples of cardinality constraints (cont.)

b) One optional, one mandatory

Maximum Cardinalities

- Looking at the MAXIMUM cardinality on BOTH sides, we classify relationships as:

1:1

1:M

M:N
Practice: Products

- We have two kinds of entities: Products and Categories. For each product we keep its id (identifier), name, price, wholesale price, and profit margin, which is calculated from the price and the wholesale price. For each category we keep its id (identifier) and its name. Each product belongs to zero or more categories and each category can have zero or more products.

Practice : CD

- Let us model a CD with three entities: CD, PERSON and SONG.
  - A CD has a number, which is its identifier, and a title
  - A person has an ID and a name, divided into first, last
  - A song has an ID, a title and a length
  - We keep track of which person is a song’s author. A person can author many songs and a song has exactly one author.
  - We keep track of which people perform on a CD. Zero or more people can perform on a CD, and people can perform on zero or more CDs.
  - We keep track of which songs are included on a CD. One or more songs are included on a CD, and a song is included in zero or more CDs.
Strong vs. Weak Entities

• Strong entity
  – Exists independently of other types of entities
  – Has its own unique identifier
  – Identifier underlined with single-line

• Weak entity
  – Dependent on a strong entity …cannot exist on its own
  – Does not have a unique identifier (only a partial identifier)
  – Partial identifier underlined with double-line
  – Entity box has double line

• Identifying relationship
  – links strong entities to weak entities

Figure 2-5 Example of a weak identity and its identifying relationship
Weak Entity → Strong Entity

Strong entity

Now a strong entity (unique ID)

Practice: Course Sections

• Model the courses using two entities: COURSE and SECTION. Each course has a number and a title, and may have zero or more sections. Each section has a number and the term offered, which is composed of semester and year.
Practice: Weak Entities

• Give another example of a weak entity type.

Relationships with Attributes
Here, the date completed attribute pertains specifically to the employee’s completion of a course…it is an attribute of the relationship.

Practice: Relationships with Attributes

- #8, page 103. The figure below shows a grade report that is mailed to students at the end of each semester. Prepare an ERD reflecting the data contained in the grade report. Assume that each course is taught by one instructor.
Practice: Relationships with Attributes

Homework Assignment

• Exercise #15(a,g), page #104
• Exercise #17, page #106
• Exercise #25, page #107
Associative Entities

- One of the hardest concepts in E-R modeling
- *An associative entity is a relationship transformed into an entity*
- Each *instance* of an associative entity represents an *instance* of the relationship
- Needed to represent ternary relationships, and for cases when we need to convert a relationship into an entity, to relate it to other entities.
Associative Entities - Example

- Previous model: a database of courses taken by employees. For each employee we keep its SSN (identifier), name and birth date, and for each course we keep its id and title. We also keep the date the employee completed that course.

- Suppose that we also want to record information about the institutions issuing the certificates. **HOW???

Figure 2-11b An associative entity (CERTIFICATE)

Associative entity is like a relationship with an attribute, but it is also considered to be an entity in its own right.

Note that the many-to-many cardinality between entities in Figure 2-11a has been replaced by two one-to-many relationships with the associative entity.
Fill in the missing cardinalities.

INSTITUTION

Institution ID
Institution Address (City, State, Zip)

Fig. 2-11: (b) An associative entity (CERTIFICATE)

What is an alternative to assign the PK?
Associative Entities

• An entity - has attributes
• A relationship - links entities together
• When should a relationship with attributes instead be an associative entity?
  – All relationships for the associative entity should be many
  – The associative entity could have meaning independent of the other entities
  – The associative entity preferably has a unique identifier, and should also have other attributes
  – The associative entity may participate in other relationships other than the entities of the associated relationship

Homework Assignment

• Exercise #15(f), page #104
Ternary Relationships

• Relationships of degree 3
• Associates three entities \textit{at the same time}
• Can't we just live with binary relationships?
Ternary Relationship - Example

• Say we wanted to keep track of which Person got which Degrees from which University.

• Can this be modeled with binary relationships?

Ternary Relationship - Example

• Yes, with the help of an associative entity

• Ternary relationship “got” is now an associative entity, DIPLOMA. Cardinality constraints?
Figure 2-12 c) Example of a ternary relationship

For example, an instance is: Vendor X Supplies Part C to Warehouse Y with a Shipping Mode of "next-day air" and a Unit Cost of $5

Note: a relationship can have attributes of its own

Fig. 2-14: Ternary relationships as an associative entity

As a general rule, ternary relationships should be converted to associative entities.
Fig. 2-18: Cardinality constraints in a ternary relationship

What are the business rules?

Practice: Ternary Relationships

• Give another example of a ternary relationship.
Homework Assignment

• Exercise #15(b), page #104
• Exercise #18, page 106

Unary Relationships
Unary Relationships

- Relationships of degree 1
- Also known as recursive relationships
- Two or more entities in the relationship are of the same type
- Example: we want to represent when an employee supervises another employee.

Example: Supervises

- Example: we want to represent when an employee supervises another employee.
- We could *start* with something like this:
Example: Supervises

- But supervisors can have their own supervisors
- Both supervisor and supervisee are employees, so we need a recursive relationship, with roles

Example: Supervises

- And, of course, add cardinalities
- **Should always define roles** – even more important when cardinalities are different

What are the business rules?
Practice: Add missing cardinalities.

Figure 2-17 Examples of cardinality constraints (cont.)

c) Optional cardinalities

A person is married to at most one other person, or may not be married at all
Example: Bill Of Materials

- Part-Whole is also a recursive relationship:

![Diagram of Part-Whole relationship]

Fig. 2-13: (b) Two ITEM bill-of-materials instances
Fig. 2-13 (c): An associative entity - bill of materials structure

This could just be a relationship with attributes…it’s a judgment call

Practice: Unary Relationships

• Give another example of a unary relationship.
Homework Assignment

• Exercise #10, page #103.

Attributes or Entity?

• Sometimes you will wonder whether to represent data as an attribute or an entity. This is a common dilemma.
• Let us look at a few situations.
Attributes or Entity?

- So when **SHOULD** an attribute be linked to an entity type via a relationship?
  - Attribute refers to a concept in the data model
  - Multiple entity instances share the same attribute
- Example on next page
Fig. 2-15: Using relationships and entities to link related attribute
(c) Composite attribute of data shared with other entity types

Multiple Relationships

- More than one relationship between the same entity types (Fig. 2-21)
Fig. 2-21: Examples of multiple relationships
(a) Employees and departments

![Diagram of Employee and Department relationships]

Entities can be related to one another in more than one way.

Fig. 2-21: (b) Professors and courses (fixed upon constraint)

**A New Business Rule:**
An instructor who is scheduled to teach a course must be qualified to teach that course?

![Diagram of Professor and Course relationships]

Here, minimum cardinality constraint is 2, what’s for?
Homework Assignment

• Exercise #11, page #103
• Exercise #15(d,i), page #105
• Exercise #18, page #106
• Exercise #20, page #106
• Exercise #23, page #107
• Exercise #26, page #108

Modeling Time-Dependent Data

Figure 2-19. Simple example of time-stamping

This attribute is both multivalued and composite.
In the middle of year, due to a reorganization of the sales function some products are reassigned to different product lines.

How to reflect product line changed over time?

<table>
<thead>
<tr>
<th>Sales</th>
<th>Product</th>
<th>Product-Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>$50,000</td>
<td>P</td>
<td>B</td>
</tr>
<tr>
<td>$40,000</td>
<td>P</td>
<td>A</td>
</tr>
</tbody>
</table>
Fig. 2-20: Pine Valley Furniture product database

Solution: adding a new relationship of “Sales_for_product_line”

(b) E-R diagram recognizing product reassignment

Fig. 2-20: Pine Valley Furniture product database

(c) E-R diagram with associative entity for product assignment to product line over time
The Entity Relationship (E-R) Model

Congratulation !!
You have just learned one of the most important modeling concept (E-R) for developing the database systems.

Recognizing Different ERD Notations
Fig. 2-22: E-R diagram for Pine Valley Furniture Company

Different modeling software tools may have different notation for the same constructs.