Data Modeling and the Entity-Relationship Model

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CS 348
Introduction to Database Management
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Outline

1. Basic E-R Modeling
   - Entities
   - Attributes
   - Relationships
   - Roles

2. Constraints in E-R Models
   - Primary Keys
   - Relationship Types
   - Existence Dependencies
   - General Cardinality Constraints

3. Extensions to E-R Modeling
   - Structured Attributes
   - Aggregation
   - Specialization
   - Generalization
   - Disjointness

4. Design Considerations
Overview of E-R Model

Used for (and designed for) database (conceptual schema) design

⇒ Proposed by Peter Chen in 1976
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World/enterprise described in terms of

- entities
- attributes
- relationships
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Visualization: E-R diagram

N.B. Many variant notations are in common use
Basic E-R Modeling

**Entity:** a *distinguishable* object

**Entity set:** set of entities of same type

Examples:
- students currently at University of Waterloo
- flights offered by Air Canada
- burglaries in Ontario during 1994

Graphical representation of entity sets:

- Student
- Flight
- Burglary
**Attributes:** describe properties of entities
Examples (for Student-entities): StudentNum, StudentName, Major, ...

**Domain:** set of permitted values for an attribute

**Graphical representation of attributes:**

```
  Student
     ↓
   StudentNum  StudentName

     ↓

  Major
```
**Relationship**: representation of the fact that certain entities are related to each other

**Relationship set**: set of relationships of a given type

Examples:
- students registered in courses
- passengers booked on flights
- parents and their children
- bank branches, customers and their accounts
Relationship: representation of the fact that certain entities are related to each other

Relationship set: set of relationships of a given type

Examples:
- students registered in courses
- passengers booked on flights
- parents and their children
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In order for a relationship to exist, the participating entities must exist.
Multiple Relationships and Role Names

**Role:** the function of an entity set in a relationship set

**Role name:** an explicit indication of a role

Example:

```
Team
TeamName
Match Location
Address
Visitor
HomeTeam
LocName
HomeTeam
Visitor
```

Role labels are needed whenever an entity set has multiple functions in a relationship set.
Relationships and Attributes

Relationships may also have attributes

Example:

```
Team
  TeamName

Score

Address
  LocName

Match
  HomeTeam
  Visitor

Visitor

HomeTeam
```
Constraints in E-R Models

- Primary keys
- Relationship types
- Existence dependencies
- General cardinality constraints
Primary Keys

Each entity must be distinguishable from any other entity in an entity set by its attributes.

**Primary key**: selection of attributes chosen by designer values of which determines the particular entity.

**Example 1:**

- Dnum
- **Department**
  - Dname
  - Budget
- **ManagerName**

**Example 2:**

- **FirstName**
- **Employee**
  - Initial
  - LastName
- **Salary**
### Relationship Types

- **many-to-many (N:N):** an entity in one set can be related to many entities in the other set, and vice versa. (This is the interpretation we have used so far.)

- **many-to-one (N:1):** each entity in one set can be related to at most one entity in the other, but an entity in the second set may be related to many entities in the first.

- **one-to-many (1:N):** similar.

- **one-to-one (1:1):** each entity in one set can be related to at most one entity in the other, and vice versa.

#### Diagrams

- **WorksIn** relationship between **Employee** and **Department**

- **Manages** relationship between **Employee** and **Department**
Existence Dependencies

Sometimes the existence of an entity depends on the existence of another entity.

If \( x \) is existence dependent on \( y \), then
- \( y \) is a dominant entity
- \( x \) is a subordinate entity

Example: “Transactions are existence dependent on accounts.”
Identifying Subordinate Entities

**Weak entity set**: an entity set containing subordinate entities

**Strong entity set**: an entity set containing no subordinate entities

Attributes of weak entity sets only form key relative to a given dominant entity

**Example**: “All transactions for a given account have a unique transaction number.”

![Entity Relationship Diagram]

- Balance
- Account
- AccNum
- Log
- Transaction
- TransNum
- Date
- Amount
A weak entity set must have a many-to-one relationship to a distinct entity set.

**Visualization:** (distinguishing an identifying relationship)

Discriminator of a weak entity set: set of attributes that distinguish subordinate entities of the set, for a particular dominant entity.

Primary key for a weak entity set: discriminator + primary key of entity set for dominating entities.
General Cardinality Constraints

General cardinality constraints determine lower and upper bounds on the number of relationships of a given relationship set in which a component entity may participate.

Visualization:

Example:

Student \( \text{Take} \) Course

\((3,5)\) \((6,100)\)
Extensions to E-R Modeling

- Structured attributes
- Aggregation
- Specialization
- Generalization
- Disjointness
Structured Attributes

Composite attributes: composed of fixed number of other attributes
Multi-valued attributes: attributes that are set-valued

Example:
Aggregation

Relationships can be viewed as higher-level entities

Example: “Accounts are assigned to a given student enrollment.”
A specialized kind of entity set may be derived from a given entity set.

**Example:** “Graduate students are students who have a supervisor and a number of degrees.”

![E-R Model Diagram]

- **Student**
  - **StudentNumber**
  - **StudentName**

- **Graduate**
  - **SupervisedBy**
    - **Professor**
      - **ProfessorName**
      - (0, N)
    - (1, 1)
  - **Degrees**
Generalization

Several entity sets can be abstracted by a more general entity set

Example: “A vehicle abstracts the notion of a car and a truck.”
Disjointness

Specialized entity sets are usually disjoint but can be declared to have entities in common

- By default, specialized entity sets are disjoint. **Example:** We may decide that nothing is both a car and a truck.
- However, we can declare them to overlap (to accommodate utility vehicles, perhaps).

![E-R Model Diagram](image-url)
Designing An E-R Schema

Usually many ways to design an E-R schema
Points to consider

- use attribute or entity set?
- use entity set or relationship set?
- degrees of relationships?
- extended features?
Attributes or Entity Sets?

Example: Should one model employees’ phones by a PhoneNumber attribute, or by a Phone entity set related to the Employee entity set?

Rules of thumb:

• Is it a separate object?
• Do we maintain information about it?
• Can several of its kind belong to a single entity?
• Does it make sense to delete such an object?
• Can it be missing from some of the entity set’s entities?
• Can it be shared by different entities?

An affirmative answer to any of the above suggests a new entity set.
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Instead of representing accounts as entities, we could represent them as relationships.
Binary vs. N-ary Relationships?

- Branch
- BranchName
- Account
- AccountNum
- CAB
- Balance
- StreetAddr
- CustomerName
- CustomerCity
- SIN

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We can always represent a relationship on $n$ entity sets with $n$ binary relationships
A Simple Methodology

1. Recognize entity sets
2. Recognize relationship sets and participating entity sets
3. Recognize attributes of entity and relationship sets
4. Define relationship types and existence dependencies
5. Define general cardinality constraints, keys and discriminators
6. Draw diagram

For each step, maintain a log of assumptions motivating the choices, and of restrictions imposed by the choices
Example: A Registrar’s Database

- Zero or more sections of a course are offered each term. Courses have names and numbers. In each term, the sections of each course are numbered starting with 1.
- Most course sections are taught on-site, but a few are taught at off-site locations.
- Students have student numbers and names.
- Each course section is taught by a professor. A professor may teach more than one section in a term, but if a professor teaches more than one section in a term, they are always sections of the same course. Some professors do not teach every term.
- Up to 50 students may be registered for a course section. Sections with 5 or fewer students are cancelled.
- A student receives a mark for each course in which they are enrolled. Each student has a cumulative grade point average (GPA) which is calculated from all course marks the student has received.
Example: A Registrar’s Database (cont’d)
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CourseNum  →  Course  →  CourseName

SectionOf

Term

CourseNum  Section

Section

TaughtBy

ProfName  ProfNum

Professor

EnrolledIn

Location

StudentNum

Student

GPA

StudentName

Mark

Off-Site

Section

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Example: A Registrar’s Database (cont.’d)

CourseNumber → Course → CourseName

(0, N)

SectionOf

Term → (1, 1)

SectionNum

(1, 1)

Section

(1, 1)

TaughtBy

Professor

ProfName

ProfNum

EnrolledIn

Student

StudentNum

StudentName

Mark

GPA

Location

Off-Site Section

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