CMSC 461, Database Management Systems
Spring 2018

Lecture 9 - Chapter 7 Entity Relationship Model

These slides are based on “Database System Concepts” 6th edition book and are a modified version of the slides which accompany the book (http://codex.cs.yale.edu/avi/db-book/db6/slide-dir/index.html), in addition to the 2009/2012 CMSC 461 slides by Dr. Kalpakis
Logistics

- Homework #2 due today
- Phase 2 due Monday 3/5/2018
- Homework #3 due 3/12/2018
Lecture Outline

- E-R Modeling
- Entity Sets & Relationship Sets
- Attributes
- Cardinality
- Keys
- E-R Diagram
- Design Issues
- Database Design Tools
Lecture Outline

• **E-R Modeling (review)**
  • Entity Sets & Relationship Sets
  • Attributes
  • Cardinality
  • Keys
  • E-R Diagram
  • Design Issues
  • Database Design Tools
Design Process

- Need modeling real world applications
- Real world applications are complex
  - They are hard to model
  - Not as easy to define relations, attributes and constraints

Based on “Database System Concepts” book and slides, 6th edition
Design Phases

- **Concept Design Phase**
  - Choose a data model
  - Translate requirements into conceptual schema (*E-R model*)
Design Alternatives

- How to **represent** types of “things” (*entities*)
- How to **relate** “things” (*relations*)

Avoid **2 major pitfalls**:
- **Redundancy**
  - repeated information
  - in the schema
- **Incompleteness**
  - Will make certain aspects of enterprise hard if not impossible to model

Based on “Database System Concepts” book and slides, 6th edition
E-R Modeling

- Useful for **mapping** meanings and interactions of real-world enterprises to conceptual schema

- 3 basic concepts:
  - Entity sets
  - Relationship sets
  - Attributes

Based on “Database System Concepts” book and slides, 6th edition
Lecture Outline

• E-R Modeling
• Entity Sets & Relationship Sets (review)
• Attributes
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Entities

- An *entity* is an object that exists and is distinguishable from other objects.
  - Example: specific person, company, event, plant
Attributes

- Entities are represented by a set of attributes
  - Example: people have names and addresses
- Attributes are descriptive properties
- For each attribute each entity has a value

Based on “Database System Concepts” book and slides, 6th edition
Entity Sets

instructor_ID  instructor_name
76766  Crick
45565  Katz
10101  Srinivasan
98345  Kim
76543  Singh
22222  Einstein

student-ID  student_name
98988  Tanaka
12345  Shankar
00128  Zhang
76543  Brown
76653  Aoi
23121  Chavez
44553  Peltier
Relationship

- A **relationship** is an association among several entities

Example:

*Dr. Johnson* advises *Jordan*

This defines an **advisor** relationship
Relationship Sets - Advisors

Relationship Sets

- An attribute can also be a property of a relationship set (descriptive attribute).
- For instance, the advisor relationship set between entity sets instructor and student may have the attribute date which tracks when the student started being associated with the advisor.

Based on and image from "Database System Concepts" book and slides, 6th edition.
Design of a Relationship

- **Binary relationship** involves two entity sets (or degree two)
  - most relationship sets in a database system are binary
Lecture Outline

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Attributes

- An entity is represented by a set of attributes, that is descriptive properties possessed by all members of an entity set.

Example:

instructor = (ID, name, street, city, salary )

course = (course_id, title, credits)
Attributes

- **Domain** – the set of permitted values for each attribute

- Attribute types:
  - **Simple** and **composite** attributes
    - Example: Name (first, middle, last)
  - **Single-valued** and **multivalued** attributes
    - Example: multivalued attribute: phone_numbers

- **Derived** attributes
  - Can be computed from other attributes
  - Example: age, given date_of_birth

Based on “Database System Concepts” book and slides, 6th edition
Composite Attributes

- **Composite attributes**
  - `first_name`
  - `middle_initial`
  - `last_name`

- **Component attributes**
  - `street_number`
  - `street_name`
  - `apartment_number`
  - `street`
  - `city`
  - `state`
  - `postal_code`
Lecture Outline

• E-R Modeling
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• Attributes
• **Cardinality (review)**
• Keys
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Mapping Cardinality Constraints

For a binary relationship set the mapping cardinality must be one of the following types:
- One to one
- One to many
- Many to one
- Many to many
Mapping Cardinality

Entity in A is associated with at most 1 entity in B and entity in B is associated with at most 1 entity in A

One to one

Based on and image from "Database System Concepts" book and slides, 6th edition
Mapping Cardinality

An entity in A is associated with any number (zero or more) of entities in B.
An entity in B is associated with AT MOST one entity in A.

Based on image from "Database System Concepts" book and slides, 6th edition
Mapping Cardinality

An entity in A is associated with AT MOST one entity in B.
An entity in B is associated with any number (zero or more) entities in A.

Based on and image from "Database System Concepts" book and slides, 6th edition
Mapping Cardinality

An entity in A is associated with any number of entities in B, and B in A

Many to many

Based on and image from "Database System Concepts" book and slides, 6th edition
Participation Constraints

- If every entity in entity set $E$ participates in at least 1 relationship in the relationship set $R$ then $R$ is said to be **total**
- The relationship set $R$ is said to be **partial** if only some entities in entity set $E$ participate

Based on and image from "Database System Concepts" book and slides, 6th edition
Lecture Outline

- E-R Modeling
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- Attributes
- Cardinality
- **Keys (review)**
- E-R Diagram
- Design Issues
- Database Design Tools
Keys

- A super key of an entity set is a set of one or more attributes whose values uniquely determine each entity.
- A candidate key of an entity set is a minimal super key:
  - ID is candidate key of instructor
  - course_id is candidate key of course
- Although several candidate keys may exist, one of the candidate keys is selected to be the primary key.

Based on “Database System Concepts” book and slides, 6th edition
Recall Our Discussion of: Keys

- Let $R$ be a set of attributes
- Let $K \subseteq R$
- $K$ is a **superkey** of $R$ if values for $K$ are sufficient to identify a unique tuple of each possible relation $r(R)$
  - Example: $\{ID\}$ and $\{ID,\text{name}\}$ are both superkeys of instructor
- Superkey $K$ is a **candidate key** if $K$ is minimal
  - Example: $\{ID\}$ is a candidate key for Instructor
## Super Keys & Candidate Keys

**What is/are the super key(s)?**

**What is/are the candidate key(s)?**

<table>
<thead>
<tr>
<th>ID</th>
<th>course_id</th>
<th>sec_id</th>
<th>semester</th>
<th>year</th>
</tr>
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<tbody>
<tr>
<td>10101</td>
<td>CS-101</td>
<td>1</td>
<td>Fall</td>
<td>2009</td>
</tr>
<tr>
<td>10101</td>
<td>CS-315</td>
<td>1</td>
<td>Spring</td>
<td>2010</td>
</tr>
<tr>
<td>10101</td>
<td>CS-347</td>
<td>1</td>
<td>Fall</td>
<td>2009</td>
</tr>
<tr>
<td>12121</td>
<td>FIN-201</td>
<td>1</td>
<td>Spring</td>
<td>2010</td>
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<tr>
<td>15151</td>
<td>MU-199</td>
<td>1</td>
<td>Spring</td>
<td>2010</td>
</tr>
<tr>
<td>22222</td>
<td>PHY-101</td>
<td>1</td>
<td>Fall</td>
<td>2009</td>
</tr>
<tr>
<td>32343</td>
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<td>1</td>
<td>Spring</td>
<td>2010</td>
</tr>
<tr>
<td>45565</td>
<td>CS-101</td>
<td>1</td>
<td>Spring</td>
<td>2010</td>
</tr>
<tr>
<td>45565</td>
<td>CS-319</td>
<td>1</td>
<td>Spring</td>
<td>2010</td>
</tr>
<tr>
<td>76766</td>
<td>BIO-101</td>
<td>1</td>
<td>Summer</td>
<td>2009</td>
</tr>
<tr>
<td>76766</td>
<td>BIO-301</td>
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<td>Summer</td>
<td>2010</td>
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<td>83821</td>
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<td>CS-190</td>
<td>2</td>
<td>Spring</td>
<td>2009</td>
</tr>
<tr>
<td>83821</td>
<td>CS-319</td>
<td>2</td>
<td>Spring</td>
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<tr>
<td>98345</td>
<td>EE-181</td>
<td>1</td>
<td>Spring</td>
<td>2009</td>
</tr>
</tbody>
</table>

Teaches

Table
Keys

- A super key of an entity set is a set of one or more attributes whose values uniquely determine each entity.
- A candidate key of an entity set is a minimal super key.
  - ID is candidate key of instructor.
  - course_id is candidate key of course.
- Although several candidate keys may exist, one of the candidate keys is selected to be the primary key.
Keys For Relationship Sets

- Keys can be used to uniquely identify relationships.
- The combination of primary keys of the participating entity sets forms a super key of a relationship set.
  - \((s\_id, i\_id)\) is the super key of advisor.
  - NOTE: this means a pair of entity sets can have at most one relationship in a particular relationship set.

Based on “Database System Concepts” book and slides, 6th edition
Keys For Relationship Sets

- Must consider the mapping cardinality of the relationship set when deciding what are the candidate keys.
- Need to consider semantics of relationship set in selecting the primary key in case of more than one candidate key.
Redundant Attributes

- Start design by identifying entity sets
- Choose identifying attributes
- Then choose relationship sets among entities
- Could result in redundant attributes across entity sets
- Try to remove
  - Only during the ER modeling phase

Based on "Database System Concepts" book and slides, 6th edition
Overview E-R Diagram

- Rectangles represent entity sets.
- Diamonds represent relationship sets.
- Attributes listed inside entity rectangle
- Underline indicates primary key attributes

Based on an image from "Database System Concepts" book and slides, 6th edition
Lecture Outline

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- Attributes
- Cardinality
- Keys
- **E-R Diagram**
- Design Issues
- Database Design Tools
Based on and image from "Database System Concepts" book and slides, 6th edition
I own a dog shelter and I want to build a system that can support me in managing the dogs and the families that adopt dogs. I like to know a lot of information about the people so I can make suggestions on what type of dog would be best for the family wishing to adopt. Some of my dogs have medical conditions I need to keep track of. After an adoption I like to check in with the family at different points in time to ensure the adoption was a success.

What are the entity sets and relationship sets involved?
I own a dog shelter and I want to build a system that can support me in managing the dogs and the families that adopt dogs. I like to know a lot of information about the people so I can make suggestions on what type of dog would be best for the family wishing to adopt. Some of my dogs have medical conditions I need to keep track of. After an adoption I like to check in with the family at different points in time to ensure the adoption was a success.

What are the entity sets and relationship sets involved?
Partial Participation of an Entity Set in a Relationship Set

- Some entities may not participate in any relationship in the relationship set
  - Example: participation of instructor in advisor is partial

Based on an image from "Database System Concepts" book and slides, 6th edition
Total Participation of an Entity Set in a Relationship Set

- Use double lines
- Every entity in entity set participates in at least one relationship in the relationship set
  - Example: participation of section in sec_course is total

Based on and image from "Database System Concepts" book and slides, 6th edition
Based on and image from "Database System Concepts" book and slides, 6th edition.
### Entity With Composite, Multivalued, and Derived Attributes

<table>
<thead>
<tr>
<th>instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ID</strong></td>
</tr>
<tr>
<td><strong>name</strong></td>
</tr>
<tr>
<td><strong>first_name</strong></td>
</tr>
<tr>
<td><strong>middle_initial</strong></td>
</tr>
<tr>
<td><strong>last_name</strong></td>
</tr>
<tr>
<td><strong>address</strong></td>
</tr>
<tr>
<td><strong>street</strong></td>
</tr>
<tr>
<td><strong>street_number</strong></td>
</tr>
<tr>
<td><strong>street_name</strong></td>
</tr>
<tr>
<td><strong>apt_number</strong></td>
</tr>
<tr>
<td><strong>city</strong></td>
</tr>
<tr>
<td><strong>state</strong></td>
</tr>
<tr>
<td><strong>zip</strong></td>
</tr>
<tr>
<td><strong>phone_number</strong></td>
</tr>
<tr>
<td><strong>{ phone_number }</strong></td>
</tr>
<tr>
<td><strong>date_of_birth</strong></td>
</tr>
<tr>
<td><strong>age ( )</strong></td>
</tr>
</tbody>
</table>

- Composite
- Composite
- Multivalued
- Derived
Relationship Sets with Attributes

Why have attributes on the relationship set?

What would be the likely primary key of advisor?
Roles

- Relationships not required to be distinct
  - Each occurrence of entity set plays a “role” in relationship
- “course_id” and “prereq_id” are called roles
- Label the lines that connect diamonds and rectangles

Based on and image from “Database System Concepts” book and slides, 6th edition
I own a dog shelter and I want to build a system that can support me in managing the dogs and the families that adopt dogs. I like to know a lot of information about the people so I can make suggestions on what type of dog would be best for the family wishing to adopt. Some of my dogs have medical conditions I need to keep track of. After an adoption I like to check in with the family at different points in time to ensure the adoption was a success.

What are some of the attributes we might have for the entity sets and relationship sets, any roles?
Cardinality Constraints

- draw directed line (→)
  - signifying “one”
- undirected line (—),
  - signifying “many”
- Between the relationship set and the entity set

Based on and image from “Database System Concepts” book and slides, 6th edition
One-to-One Relationship

- Between an instructor and a student
  - an instructor is associated with at most one student via advisor
  - and a student is associated with at most one instructor via advisor
One-to-Many Relationship

- one-to-many relationship between instructor and student
  - an instructor is associated with 0 to many students via advisor
  - a student is associated with at most one instructor via advisor

Based on and image from "Database System Concepts" book and slides, 6th edition
Many-to-One Relationship

- many-to-one relationship between instructor and student,
  - an instructor is associated with at most one student via advisor,
  - a student is associated with 0 to many instructors via advisor

Based on and image from "Database System Concepts" book and slides, 6th edition
Many-to-Many Relationship

- An instructor is associated with 0 to many students via advisor.
- A student is associated with 0 to many instructors via advisor.

Based on and image from "Database System Concepts" book and slides, 6th edition.
Alternative Notation for Cardinality Limits

- Cardinality limits can also express participation constraints

Each student has exactly one advisor
An instructor can advise 0 to many students
Alternative Notation for Cardinality Limits

Notations for showing cardinality (multiplicity)

<table>
<thead>
<tr>
<th>Notation</th>
<th>UML</th>
<th>Chen</th>
<th>Crow's Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>one and only one</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>one or more</td>
<td>1..*</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>any number</td>
<td>*</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>optional</td>
<td>0..1</td>
<td>M</td>
<td></td>
</tr>
</tbody>
</table>

Based on and image from "Database System Concepts" book and slides, 6th edition
In-Class Exercise

- Is it one-to-one, one-to-many, many-to-one, or many-to-many?
  - Owner and Car
  - Person and Job
  - Person and Weight
  - Person and Mother (Birth)
  - Husband and Wife
I own a dog shelter and I want to build a system that can support me in managing the dogs and the families that adopt dogs. I like to know a lot of information about the people so I can make suggestions on what type of dog would be best for the family wishing to adopt. Some of my dogs have medical conditions I need to keep track of. After an adoption I like to check in with the family at different points in time to ensure the adoption was a success.

What is the cardinality of the relationships?
Weak Entity Sets

- **Weak entity set** - An entity set that does not have a primary key
- **Strong entity set** - An entity set that has a primary key
- **Identifying entity set** – entity set that is associated with a weak entity set
  - Weak entity set is *existence dependent* on identifying entity set
  - Identifying entity set “owns” weak entity set

Based on and image from "Database System Concepts" book and slides, 6th edition
Weak Entity Sets

- **Identifying relationship** - Relationship associating weak entity set with identifying entity set
  - Many-to-one from weak entity set to identifying entity set
  - Participation of weak entity set in relationship set is total
  - No descriptive attributes
  - depicted using a double diamond
Weak Entity Sets

- **Discriminator** - *set of attributes that allow distinction among entities in weak entity set*
  - *Also called partial key*
- The primary key of a weak entity set is formed by the primary key of the strong entity set on which the weak entity set is existence dependent, plus the weak entity set’s discriminator

Based on and image from "Database System Concepts" book and slides, 6th edition
Weak Entity Sets

- We underline the discriminator of a weak entity set with a dashed line
- We put the identifying relationship of a weak entity in a double diamond
- Primary key for \textit{section} – \((\text{course\_id}, \text{sec\_id}, \text{semester}, \text{year})\)

Based on an image from "Database System Concepts" book and slides, 6th edition
Weak Entity Sets

- Note: the primary key of the strong entity set is not explicitly stored with the weak entity set, since it is implicit in the identifying relationship.
- If `course_id` were explicitly stored, `section` could be made a strong entity, but then the relationship between `section` and `course` would be duplicated by an implicit relationship defined by the attribute `course_id` common to `course` and `section`.

Based on and image from "Database System Concepts" book and slides, 6th edition
E-R Diagram for University Enterprise

- Name an example of a weak entity set in the university schema?
I own a dog shelter and I want to build a system that can support me in managing the dogs and the families that adopt dogs. I like to know a lot of information about the people so I can make suggestions on what type of dog would be best for the family wishing to adopt. Some of my dogs have medical conditions I need to keep track of. After an adoption I like to check in with the family at different points in time to ensure the adoption was a success.

Are there any weak entity sets?
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- E-R Diagram
- *Design Issues*
- Database Design Tools
Design Issues – Entity Sets vs. Attributes

- Use of phone as an entity allows extra information about phone numbers (plus multiple phone numbers)

Based on and image from “Database System Concepts” book and slides, 6th edition
Design Issues – Entity Sets vs. Attributes

- Key Mistakes:
  - Using primary key of an entity set as an attribute of another entity set
    * Student ID in Instructor relation
  - Designation of primary keys as attributes of the relation set

Based on and image from "Database System Concepts" book and slides, 6th edition
Design Issues – Entity Sets vs. Relationship Sets

- Possible guideline is to designate a relationship set to describe an action that occurs between entities.

Here we used a registration entity set instead of the takes relationship set.

Based on and image from "Database System Concepts" book and slides, 6th edition
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• *Database Design Tools*
E-R Diagramming Tools - Lucid
E-R Diagramming Tools - Lucid
E-R Diagramming Tools – draw.io
E-R Diagramming Tools – draw.io
E-R Diagramming Tools – draw.io
E-R Diagramming Tools – dia
E-R Diagramming Tools – dia
E-R Diagramming Tools – dia
E-R Diagramming Tools – Visual Paradigm

Entity relationship diagram

Entity Relationship Diagram (ERD) is a database design tool that provides graphical representation of database tables, the columns in tables and the relationships between tables. With neat organization of tables, table columns and flexible representation of cardinalities, ERD is extremely helpful in modeling databases that have a large amount of tables and with complex relationships in between. A well-developed ERD can provide sufficient information for database administrator to follow when developing and maintaining database.