Relational Database Design
Part I

CPS 196.3
Introduction to Database Systems

Announcement

- Change the password of your DB2 account
  - Let me know if you have NOT received the email
- New schedule starting next week:
  12:50pm-2:05pm Mondays and Wednesdays
- Homework #1 will be assigned next Wednesday
  - Some relational algebra problems will be posted on the newsgroup over the weekend
  - You can start early!

Relational model: review

- A database is a collection of relations (or tables)
- Each relation has a list of attributes (or columns)
- Each attribute has a domain (or type)
- Each relation contains a set of tuples (or rows)
Keys

- A set of attributes \( K \) is a key for a relation \( R \) if
  - In no instance of \( R \) will two different tuples agree on all attributes of \( K \)
    - That is, \( K \) is a “tuple identifier”
  - No proper subset of \( K \) satisfies the above condition
    - That is, \( K \) is minimal

- Example: \( \textit{Student} (\textit{SID}, \textit{name}, \textit{age}, \textit{GPA}) \)
  - \( \textit{SID} \) is a key of \( \textit{Student} \)
  - \{\( \textit{SID}, \textit{name} \)\} is not a key (not minimal)

Schema vs. data

- \( \textit{Student} \)

<table>
<thead>
<tr>
<th>ID</th>
<th>name</th>
<th>age</th>
<th>GPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>142</td>
<td>Bart</td>
<td>10</td>
<td>2.3</td>
</tr>
<tr>
<td>123</td>
<td>Milhouse</td>
<td>10</td>
<td>1.1</td>
</tr>
<tr>
<td>357</td>
<td>Lisa</td>
<td>8</td>
<td>4.3</td>
</tr>
<tr>
<td>564</td>
<td>Ralph</td>
<td>8</td>
<td>2.3</td>
</tr>
</tbody>
</table>

- Is \( \textit{name} \) a key of \( \textit{Student} \)?

- Key declarations are part of the schema

More examples of keys

- \( \textit{Enroll} (\textit{SID}, \textit{CID}) \)
- ...

- \( \textit{Address} (\textit{street_address}, \textit{city}, \textit{state}, \textit{zip}) \)
- ...
- ...
Usage of keys

- More constraints on data, fewer mistakes
- Look up a row by its key value
  - Many selection conditions are “key = value”
- “Pointers”
  - Example: Enroll (SID, CID)
    - SID is a key of Student
    - CID is a key of Course
    - An Enroll tuple “links” a Student tuple with a Course tuple
  - Many join conditions are “key = key value stored in another table”

Database design

- Understand the real-world domain being modeled
- Specify it using a database design model
  - Design models are especially convenient for schema design, but are not necessarily implemented by DBMS
  - Popular ones include
    - Entity/Relationship (E/R) model
    - Object Definition Language (ODL)
- Translate specification to the data model of DBMS
  - Relational, XML, object-oriented, etc.
- Create DBMS schema

Entity-relationship (E/R) model

- Historically very popular
- Can think of as a “watered-down” object-oriented design model
- E/R diagrams represent designs
- Primarily a design model—not implemented by any major DBMS
E/R basics
- Entity: a "thing," like a record or an object
- Entity set: a collection of things of the same type, like a relation of tuples or a class of objects
  - Represented as a rectangle
- Relationship: an association among two or more entities
- Relationship set: a set of relationships of the same type; an association among two or more entity sets
  - Represented as a diamond
- Attributes: properties of entities or relationships, like attributes of tuples or objects
  - Represented as ovals

An example E/R diagram
- Students enroll in courses

A key of an entity set is represented by underlining all attributes in the key
- A key is a set of attributes whose values can belong to at most one entity in an entity set—like a key of a relation

Attributes of relationships
- Example: students take courses and receive grades

Where do the grades go?
- With Students?
- With Courses?
- With Enroll!
More on relationships

- There could be multiple relationship sets between the same entity sets
  - Example: Students Enroll Courses; Students TA Courses
- In a relationship set, each relationship is uniquely identified by the entities it connects
  - Example: Between Bart and CPS196, there can be at most one Enroll relationship and at most one TA relationship
  - What if Bart took CPS196 twice and got two different grades?

Multiplicity of relationships

- $E$ and $F$: entity sets
- Many-many: Each entity in $E$ is related to 0 or more entities in $F$ and vice versa
  - Example: 
    - Students [enroll] Courses
- Many-one: Each entity in $E$ is related to 0 or 1 entity in $F$, but each entity in $F$ is related to 0 or more in $E$
  - Example: 
    - Course [taught by] Instructor
- One-one: Each entity in $E$ is related to 0 or 1 entity in $F$ and vice versa
  - Example: 
    - Students [own] AcpubAccounts
- Notation: "One" (0 or 1) is represented by an arrow

N-ary relationships

- Example: Each course has multiple TA’s; each student is assigned to one TA
  - Students [enroll] Courses [TA’s]
- Meaning of an arrow into $E$: Pick one entity from each of the other entity sets; together they must be related to either 0 or 1 entity in $E
N-ary versus binary relationships

- Can we model \( n \)-ary relationships using just binary relationships?

Students Enroll Courses

AssignedTo Assist

Roles in relationships

- An entity set may participate more than once in a relationship set
- May need to label edges to distinguish roles
- Examples
  - People are married as husband and wife; label needed
  - People are roommates of each other; label not needed

Persons Marry

husband

wife

Weak entity sets

- Sometimes the key of an entity set \( E \) comes not completely from its own attributes, but from the keys of other (one or more) entity sets to which \( E \) is linked by many-one (or one-one) relationship sets
  - \( E \) is called a weak entity set
    - Represented by double rectangle
  - Many-one (or one-one) relationship sets required
    - Represented by double diamonds
    - With many-many, we would not know which entity provides the key value
Weak entity set examples

- Seats in rooms in buildings

Modeling $n$-ary relationships

- An $n$-ary relationship set can be replaced by a weak entity set (called a connecting entity set) and $n$ binary relationship sets

ISA relationships

- Similar to the idea of subclasses in object-oriented programming: subclass = special case, more properties, and fewer entities
- Represented as a triangle (direction is important)
- Example: Graduate students are students, but they also have offices
Summary of E/R concepts

- Entity sets
  - Keys
  - Weak entity sets
- Relationship sets
  - Attributes of relationships
  - Multiplicity
  - Roles
  - Binary versus N-ary relationships
    - Modeling N-ary relationships with weak entity sets and binary relationships
  - ISA relationships

Case study 1

- Design a database representing cities, counties, and states
  - For states, record name and capital (city)
  - For counties, record name, area, and location (state)
  - For cities, record name, population, and location (county and state)
- Assume the following:
  - Names of states are unique
  - Names of counties are only unique within a state
  - Names of cities are only unique within a county
  - A city is always located in a single county
  - A county is always located in a single state

Case study 1: first design
Case study 1: second design

Cities
- name
- population

Counties
- name
- area

Status

Case study 2

Design a database consistent with the following:
- A station has a unique name and an address, and is either an express station or a local station
- A train has a unique number and an engineer, and is either an express train or a local train
- A local train can stop at any station
- An express train only stops at express stations
- A train can stop at a station for any number of times during a day
- Train schedules are the same everyday

Case study 2: first design

Trains
- number
- engineer
- E/L?

StopsAt
- Stations
- name
- address
- E/L?
- time
Case study 2: second design