COS 597A:
Principles of
Database and Information Systems

Relational model

Relational model

- A formal (mathematical) model to represent
  - objects (data/information),
  - relationships between objects
  - Constraints on objects and relationships
  - Queries about information
- Well-founded on mathematical principles :
  - Precise semantics of constraints and queries
  - Can prove equivalence of different ways to express queries

Relational model - practice

- Foundation of most Database Management Systems
- SQL language is a programming language to express constructs of formal model

Relational Database Definitions

1. A relation is a set of tuples over specified domains
   - R subset of D_1 X D_2 X D_3 X … D_k (k-ary)
   - Each D_i is a declared domain
   - Domains atomic
     - *types* of programming languages
2. A relational database is a set of relations and possibly constraints among the relations

Relational Database: Terminology

Schema for a relation:

1. Relation name
2. Domain (type) of each component
   i.e. declare D_i s

Equivalent:

- Instance of a scheme
- Table

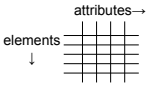
Term "relation" is used to refer to a schema and a particular instance – disambiguate by context

Relational Database: More Terminology

Each D_i of a schema is referred to as a component or attribute or field or column of the schema

Each d_i of a tuple = (d_1, d_2, d_3, … d_k) is referred to as component or attribute or field of the tuple

Each tuple of a relation is also referred to as an element or row of the relation



Translating ER model to relational

- Domains → domains
- Entity → relation
- Relationship → one* or more relations
  * come back to
- Constraints → constraints BUT
  - ➢Not all ER constraints expressible in basic relational model

Relational model is FLAT – no hierarchy!

Our ER Example → Relational schema

For entities, get relations:

books: (title, ISBN#, edition, date)
authors:
(name, gender, birth date, place of birth, date of death)
publishers: (name, country, address)

Need declare domains:
e.g. title: string

Same defs *candidate keys*, *primary key*, *superkeys*

Our ER Example → Relational schema

For relationships:

ER *published by*: (***books***, ***publishers***, in print)
becomes
published by: (*isbn#, publisher_name*, in print)
key constraint on entity *books* in relationship *published by* →
A book has at most one publisher

ER *written by*: (***books***, ***authors***)
becomes
written by:
(*isbn#, author_name, birth date, place of birth*)

Our ER Example → Relational schema

Because ER key constraint on entity *books* in relationship *published by*
Can fold relation *published by* into relation *books:*

books:
(title, ISBN#, edition, date, pub_name, in print)

What if some books not published?
i.e. entity *books* not totally participate in relationship *published by*

Our ER Example → Relational schema

books:
(title, ISBN#, edition, date, pub_name, in print)

What if some books not published?
i.e. entity *books* not totally participate in relationship *published by*

Must allow values of attributes
pub_name and *in print* to be null

Translating ER model to relational

General conclusion:
Relationship → ~~one~~ zero or more relations

Translating ER model to relational

- Get flat set of relations
- But relations are interrelated
  - Bring together primary keys of different relations to build new relation
  - Captures ER relationship
- How capture this in relational model?
  Foreign key constraints

Foreign key constraint

- Specify that a set of attributes in schema for one relation form a primary key for a specific other relation
  - "other relation" is referred to or referenced by first relation

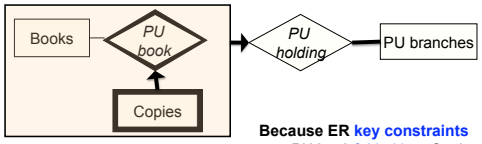
R1: (attrib1, attrib2, attrib3, attrib4, attrib5)
R1 refers to/references R2
R2: (attrib1, attrib2, attrib3, attrib4)

Foreign Keys for Our Example

published by: (*isbn#, publisher_name*, in print)
isbn# is a foreign key referencing *books*
Primary key of *books* understood
Publisher_name is a foreign key referencing *publishers*

written by:
(*isbn#, author_name, birth date, place of birth*)
isbn# is a foreign key referencing *books;*
(author_name, birth date, place of birth) is a foreign key referencing *authors*

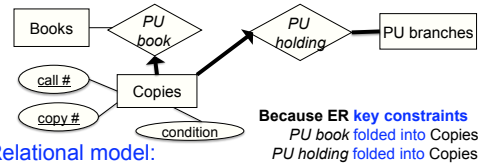
Summary of board example: with Copies as weak entity



Because ER key constraints
PU book folded into Copies
PU holding folded into Copies

Relational model:
Books: (title, ISBN#, edition, date)
PU branches: (br_name, librarian, hours)
Copies: (ISBN#, copy#, condition, br_name)
br_name not null
isbn# is a foreign key referencing ***Books***
br_name is a foreign key referencing ***PU branches***

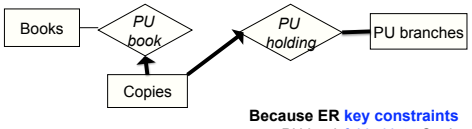
Summary of board example: with Copies as strong entity



Because ER key constraints
PU book folded into Copies
PU holding folded into Copies

Relational model:
Books: (title, ISBN#, edition, date)
PU branches: (br_name, librarian, hours)
Copies: (ISBN#, call #, copy #, condition, br_name)
br_name not null
ISBN# not null ⇦ NEW
isbn# is a foreign key referencing ***Books***
br_name is a foreign key referencing ***PU branches***

Summary of board example: Alternative with Copies as strong entity



Because ER key constraints
PU book folded into Copies

Relational model:
Books: (title, ISBN#, edition, date)
PU branches: (br_name, librarian, hours)
Copies: (ISBN#, call #, copy #, condition)
ISBN# not null
isbn# is a foreign key referencing ***Books***
PU holding: (call #, copy #, br_name)
(call #, copy #) is a foreign key referencing ***Copies***
br_name is a foreign key referencing ***PU branches***

Board example: Total participation of Copies?

Copies: (ISBN#, call #, copy #, condition, br_name)

br_name not null
ISBN# not null
isbn# is a foreign key referencing ***Books***
br_name is a foreign key referencing ***PU branches***

capture total participation in *PU book* and *PU holding* because *PU book*, *PU holding* represented within *Copies*

versus

PU holding: (call #, copy #, br_name)
(call #, copy #) is a foreign key referencing ***Copies***
br_name is a foreign key referencing ***PU branches***

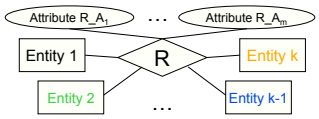
br_name "not null" would not capture that ***every*** (call #, copy #) value is in a *PU holding* pair

Board example: Total participation of PU branches?

Can't get constraint applied to all *PU branch* tuples without being part of *PU branch* relation

⇨Total participation of *PU branches* in *PU holding* not representable in pure relational definition

Basic Paradigm



- Each entity becomes a relation
- Relationship becomes

R: { (list of attributes forming key of Entity 1 (denote L_1), list of attributes forming key of Entity 2 (denote L_2), … list of attributes forming key of Entity k (denote L_k), Attribute R_A_1, …, Attribute R_A_m)
L_1 is a foreign key referencing Entity 1,
…
L_k is a foreign key referencing Entity k }

Note primary key

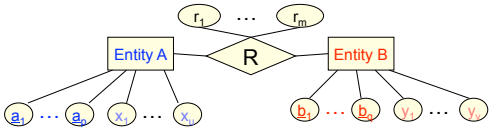
What about constraints on relationships?

- Key constraint:
  - Simplifies key of corresponding relation
  - Allows folding of relation into key entity
- Total participation constraint:
  - In general, cannot represent in purely relational definition:
    - Domain specification
    - Keys of relations
    - Foreign keys
    - "not null"s

} Constraints have in relational definition

Clarifying null values and foreign keys

For Basic Paradigm (binary relationship)

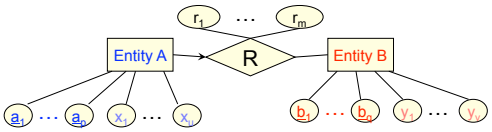


- Each entity becomes a relation with same attributes
- Relationship becomes

R: { (a_1,…, a_p, b_1, …, b_q, r_1, …, r_m)
(a_1, …, a_p) is a foreign key referencing A,
(b_1, …, b_q) is a foreign key referencing B }

can be no null values among a_i and b_j in tuple of R make up R's primary key

When one entity (e.g. Entity A) has key constraint and fold R into it

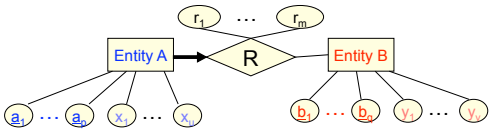


•Entity B becomes a relation with same attributes
• Relationship R becomes *part* of relation for Entity A:

A: { ($\underline{a_1}$,…, $\underline{a_p}$, x_1, …, x_u, b_1, …, b_q, r_1, …, r_m)
(b_1, …, b_q) is a foreign key referencing B }

now need to allow null values for b_1 … b_q in A
not every entity in A is related to an entity in B

When have key constraint ***and total participation*** and fold R in



• Entity B becomes a relation with same attributes
• Relationship R becomes *part* of relation for Entity A:

A: { ($\underline{a_1}$,…, $\underline{a_p}$, x_1, …, x_u, b_1, …, b_q, r_1, …, r_m)
(b_1, …, b_q) is a foreign key referencing B
b_1 not null, …, b_q not null }

now prohibit null values for b_1 … b_q in A
every entity in A is related to an entity in B

Enforcing relational constraints

- Constraints must be satisfied at all times
- What happens when tuples in relations change?

- Action of changing a relation not part of basic relational model
- Database language implementing model enforces

Enforcement in SQL

SQL commands changing relations:
INSERT, DELETE, UPDATE

- Domain constraints
  - Don't allow attribute value not in domain
    INSERT or UPDATE fails
- "Not null" constraints
  - Special case of domain constraints

Enforcement in SQL

- Candidate key constraints
  - Can have other candidate keys declared as well as primary key
  - Don't allow 2nd tuple with same key value
    INSERT or UPDATE fails
  - Implicit "not null" for attributes in a key
    INSERT or UPDATE fails

Enforcement in SQL

- Foreign key constraints

Suppose Y denotes a set of attributes of relation B that reference the primary key of relation A.

  - Don't allow tuple into B if no tuple in A with matching values for Y
    INSERT or UPDATE fails

Enforcement in SQL

Foreign key constraints continued
- suppose want to remove a tuple in A
- Suppose there is a tuple in B with matching values for Y

Choices (in SQL):
1. Disallow deletion from A
   DELETE or UPDATE fails

Enforcement in SQL

Choices (in SQL) continued:
2. Ripple effect (CASCADE):
   - Remove tuple from A and all tuples from B with matching values for Y
   - DELETE or UPDATE in A causes DELETE in B
3. Substitute value
   - Put "null" (if Y not part of candidate key for B) or other default value for Y in B
   - DELETE or UPDATE in A causes UPDATE in B

Actions for board example?

Books: (title, ISBN#, edition, date)

PU branches: (br_name, librarian, hours)

Copies: (ISBN#, copy#, condition, purchase date, br_name)
br_name not null
isbn# is a foreign key referencing ***books***
br_name is a foreign key referencing ***PU branches***

What about constraints not expressible in ER model?

- Value-based constraints?
- General functional constraints?

In relational model:
- Declaring and enforcing these depend on use of database language
- Use query semantics to check