

# COSC 304

## Introduction to Database Systems

### ER to Relational Mapping

**Dr. Ramon Lawrence**  
**University of British Columbia Okanagan**  
 ramon.lawrence@ubc.ca

## ER Model to Relational Schemas

These notes will describe how to convert an ER diagram (or EER diagram) into a corresponding relational schema.

Conceptual database design produces a conceptual ER model. This conceptual model is then converted into the relational model (which is a logical model).

Note that although it is possible to design using the relational model directly, it is normally more beneficial to perform conceptual design using the ER model first.

## ER Model to Relational Schemas (2)

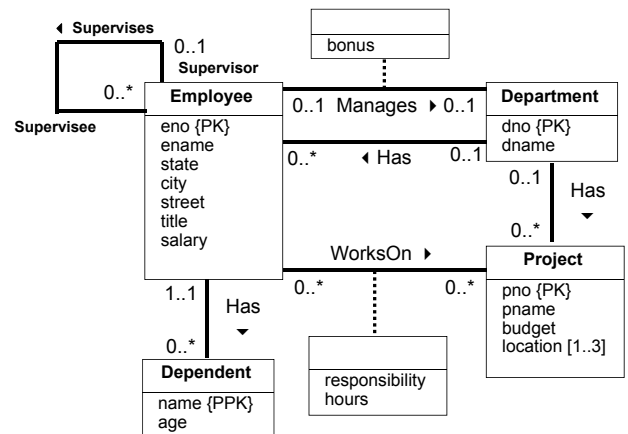
Converting an ER model to a relational database schema involves 7 steps.

In general, these steps convert entities to relations and ER relationships to relations. For 1:1 and 1:N relationships, foreign keys can be used instead of separate relations.

Handling subclasses and superclasses in the EER model requires an extra conversion step.

After conversion is performed, normalization and optimization are often performed to improve the relational schema.

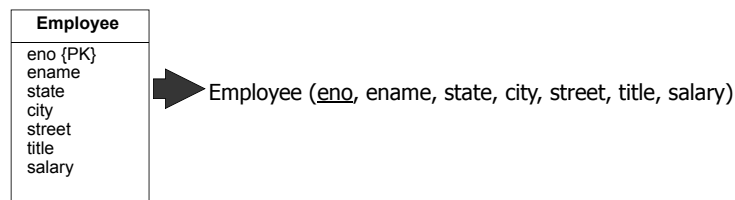
## ER Model Example



## ER to Relational Mapping

### Step #1: Convert Strong Entities

Step #1: Convert each strong entity to a relation.



#### ◆Notes:

- ⇒ 1) Attributes of the entity type become attributes of the relation.
- ⇒ 2) Include only simple attributes in relation. For composite attributes, only create attributes in the relation for their simple components.
- ⇒ 3) Multi-valued attributes are handled separately (in step #6).
- ⇒ 4) The primary key of the relation is the key attributes for the entity.

## ER to Relational Mapping

### Current Relational Schema - Step #1

Employee (eno, ename, state, city, street, title, salary)

Project (pno, pname, budget)

Department (dno, dname)

## ER to Relational Mapping

### Step #2: Convert Weak Entities

Step #2: Convert each weak entity into a relation with foreign keys to its identifying relations (entities).

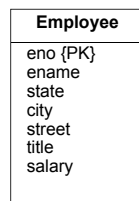
For each weak entity  $W$  with identifying owners  $E_1, E_2, \dots, E_n$  create a relation  $R$ :

- ◆ Identify relations  $R_1, R_2, \dots, R_n$  for entity types  $E_1, E_2, \dots, E_n$ .
- ◆ The primary key of  $R$  consists of the primary keys of  $R_1, R_2, \dots, R_n$  plus the partial key of the weak entity.
- ◆ Create a foreign key in  $R$  to the primary key of each relation  $R_1, R_2, \dots, R_n$ .
- ◆ Attributes are converted the same as strong entities.

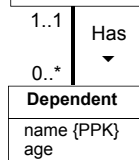
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## ER to Relational Mapping

### Step #2: Convert Weak Entities (2)



Employee (eno, ename, state, city, street, title, salary)



Dependent (eno, name, age)

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## ER to Relational Mapping

### Current Relational Schema - Step #2

Dependent (eno, name, age)

Employee (eno, ename, state, city, street, title, salary)

Project (pno, pname, budget)

Department (dno, dname)

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## ER to Relational Mapping

### Steps #3-5: Convert Relationships

Steps 3 to 5 convert *binary* relationships of cardinality:

- ◆ 1:1 - Step #3
- ◆ 1:N - Step #4
- ◆ M:N - Step #5

Note that M:N relationships are the most general case, and the conversion algorithm for these relationships can be applied to 1:1 and 1:N as well.

- ◆ However, for performance reasons, it is normally more efficient to perform different conversions for each relationship type.
- ◆ In general, each ER relationship can be mapped to a relation. However, for 1:1 and 1:N relationships, it is more efficient to combine the relationship with an existing relation instead of creating a new one.

Relationships that are not binary are handled in step #7. Page 10

## ER to Relational Mapping

### Step #3: Convert 1:1 Relationships

Step #3: Convert binary 1:1 relationships into a **UNIQUE** foreign key reference from one relation to the other.

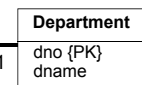
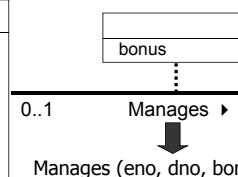
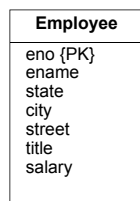
Given a binary 1:1 relationship  $R$  between two entities  $E_i$  and  $E_j$ :

- ◆ Identify the corresponding relations  $R_i$  and  $R_j$ .
- ◆ Chose one of the relations, say  $R_i$ , and:
  - ⇒ Add the attributes of  $R$  to  $R_i$ .
  - ⇒ Add the primary key attributes of  $R_j$  to  $R_i$ , and create a foreign key reference to  $R_j$  from  $R_i$ .
  - ⇒ Declare these primary key attributes of  $R_j$  to be **UNIQUE**.
- ◆ Notes:
  - ⇒ You can select either  $R_i$  or  $R_j$ . Typically, it is best to select the relation that is guaranteed to always participate in the relationship or the one that will participate the most in the relationship.

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## ER to Relational Mapping

### Step #3: Convert 1:1 Relationships (2)



Department (dno, dname)

Employee (eno, ename, state, city, street, title, salary)

Department (dno, dname, **mgreno**, bonus)

Note: Renamed eno to mgreno for clarity.

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## ER to Relational Mapping

### Step #4: Convert 1:N Relationships

Step #4: Convert binary 1:N relationships between into a foreign key reference from the N-side relation to the 1-side relation.

Given a binary 1:N relationship  $R$  between two entities  $E_i$  and  $E_j$ :

- ◆ Identify the corresponding relations  $R_i$  and  $R_j$ .
- ◆ Let  $R_i$  be the N-side of the relationship.
  - ⇒ Add the attributes of  $R$  to  $R_i$ .
  - ⇒ Add the primary key attributes of  $R_j$  to  $R_i$ , and create a foreign key reference to  $R_j$  from  $R_i$ .

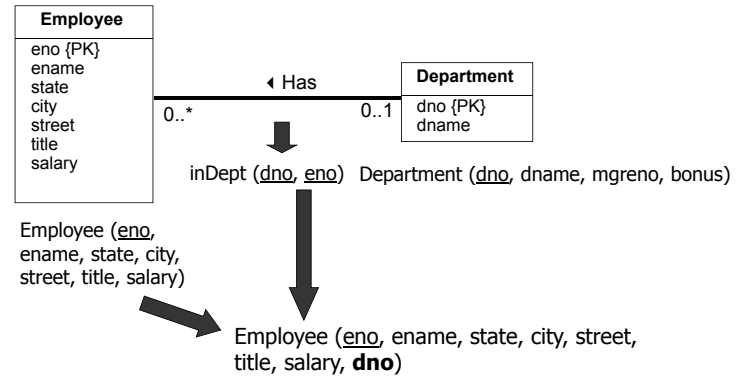
Notes:

- ◆ Unlike 1:1 relationships, you must select the N-side of the relationship as the relation containing the foreign key and relationship attributes.

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## ER to Relational Mapping

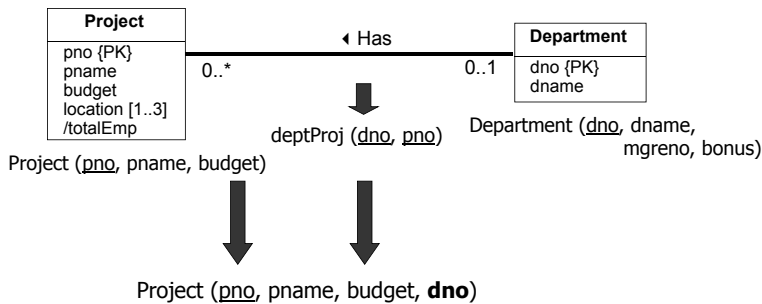
### Step #4: Convert 1:N Relationships



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## ER to Relational Mapping

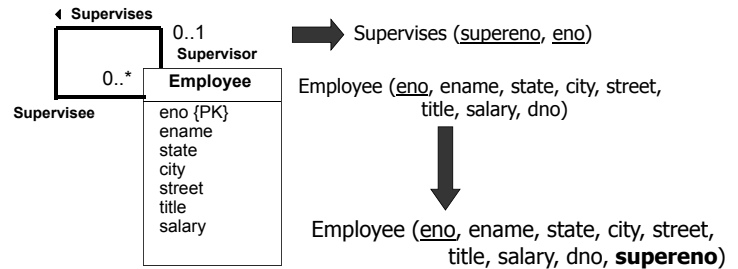
### Step #4: Convert 1:N Relationships



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## ER to Relational Mapping

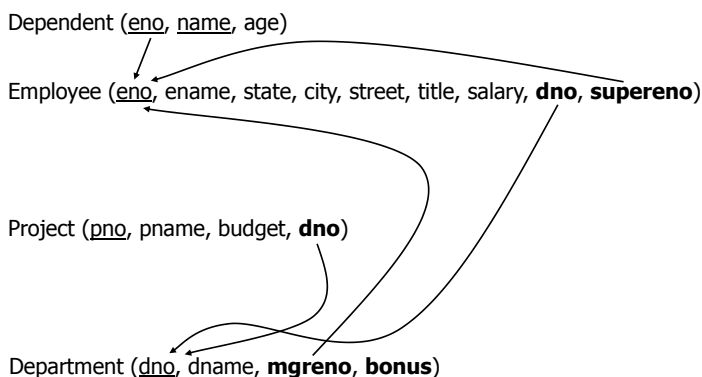
### Step #4: Convert 1:N Relationships



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## ER to Relational Mapping

### Current Relational Schema - Step #4



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## ER to Relational Mapping

### Step #5: Convert M:N Relationships

Step #5: Convert binary M:N relationships into a new relation with foreign keys to the two participating entities.

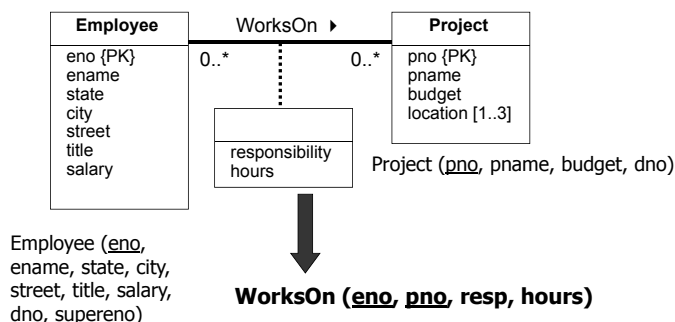
Given a binary M:N relationship between entities  $E_i$  and  $E_j$ :

- ◆ Identify the corresponding relations  $R_i$  and  $R_j$ .
- ◆ Create a new relation  $R$  representing the relationship where:
  - ⇒  $R$  contains the relationship attributes.
  - ⇒ The primary key of  $R$  is a composite key consisting of the primary keys of  $R_i$  and  $R_j$ .
  - ⇒ Add the primary key attributes of  $R_i$  and  $R_j$  to  $R$ , and create a foreign key reference to  $R_i$  from  $R$  and to  $R_j$  from  $R$ .

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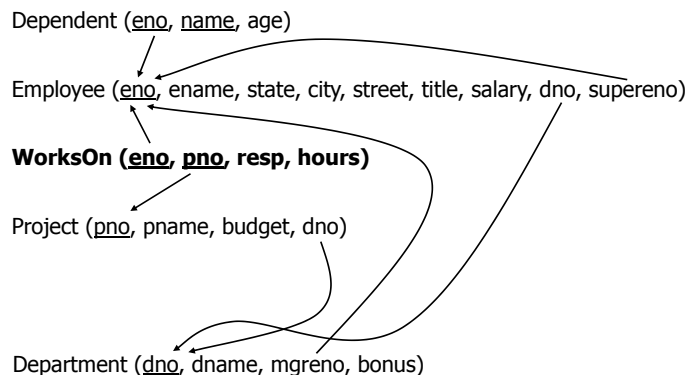
## ER to Relational Mapping

### Step #5: Convert M:N Relationships



## ER to Relational Mapping

### Current Relational Schema - Step #5



## ER to Relational Mapping

### Step #6: Convert Multi-Valued Attributes

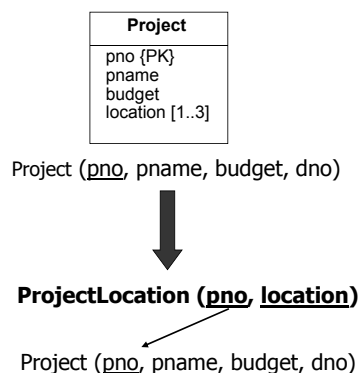
Step #6: Convert a multi-valued attribute into a relation with composite primary key consisting of the attribute value plus the primary key of the attribute's entity.

Given a multi-valued attribute  $A$  of entity  $E_i$ :

- ◆ Identify the corresponding relation  $R_i$ .
- ◆ Create a new relation  $R$  representing the attribute where:
  - ⇒  $R$  contains the simple, single-valued attribute  $A$ .
  - ⇒ Add the primary key attributes of  $R_i$  to  $R$ , and create a foreign key reference to  $R_i$  from  $R$ .
  - ⇒ The primary key of  $R$  is a composite key consisting of the primary key of  $R_i$  and  $A$ .

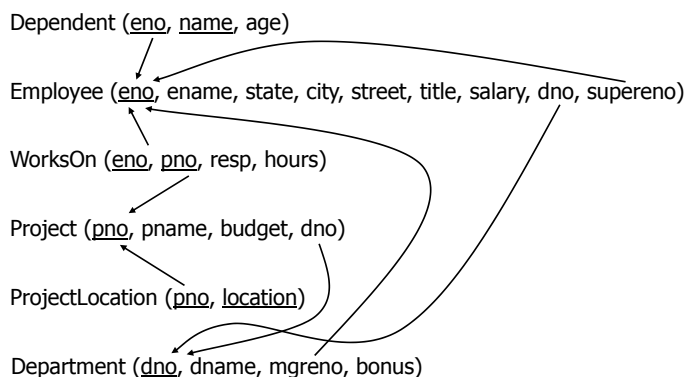
## ER to Relational Mapping

### Step #6: Convert Multi-Valued Attributes



## ER to Relational Mapping

### Final Relational Schema



## ER to Relational Mapping

### Step #7: Convert n-ary Relationships

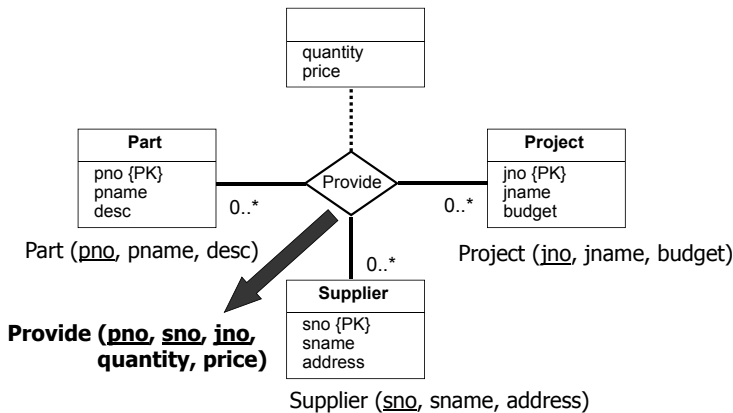
Step #7: Convert  $n$ -ary relationships by creating a new relation to represent the relationship and creating foreign keys that reference the related entities.

Given an  $n$ -ary relationship between entities  $E_1, E_2, \dots, E_n$ :

- ◆ Identify relations  $R_1, R_2, \dots, R_n$  for entity types  $E_1, E_2, \dots, E_n$ .
- ◆ Create a new relation  $R$  to represent the relationship.
- ◆ The primary key of  $R$  consists of the primary keys of  $R_1, R_2, \dots, R_n$ .
- ◆ Create a foreign key in  $R$  to the primary key of each relation  $R_1, R_2, \dots, R_n$ .
- ◆ Attributes of the relationship become attributes of  $R$ .

## ER to Relational Mapping

### Step #7: Convert n-ary Relationships



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## EER to Relational Mapping

An additional step is necessary to convert subclasses and superclasses to the relational model.

We have several different approaches:

- ◆ 1) Create a separate relation for each superclass and subclass.
  - ⇒ Most general technique that we will use.
- ◆ 2) Create relations for subclass only.
  - ⇒ Only works if superclass has mandatory participation.
- ◆ 3) Create a single relation with one type attribute.
  - ⇒ Attribute is used to indicate the type of object (subclass) in the row.
  - ⇒ Works only if the subclasses are disjoint.
- ◆ 4) Create a single relation with multiple type attributes.
  - ⇒ Have a boolean valued attribute for each subclass. True if in subclass.
  - ⇒ Works if subclasses may be overlapping.

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## ER to Relational Mapping

### Step #8: Convert Subclasses

Step #8: Convert subclasses and superclasses by creating a relation for each subclass and superclass. Link the subclasses to the superclass using foreign key references.

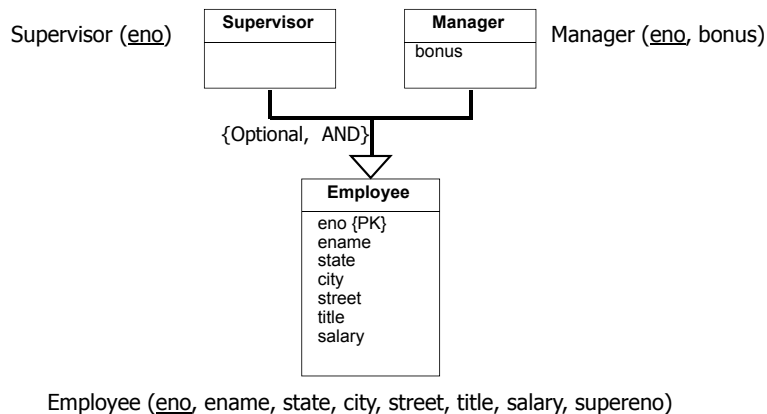
Given a superclass  $C$  and set of subclasses  $S_1, S_2, \dots, S_n$ :

- ◆ Create a relation  $R$  for  $C$ .
- ◆ The primary key for  $R$  is the primary key of the superclass.
- ◆ Create relations  $R_1, R_2, \dots, R_n$  for subclasses  $S_1, S_2, \dots, S_n$ .
- ◆ The primary key for each  $R_i$  is the primary key of the superclass.
- ◆ For each  $R_i$ , create a foreign key to  $R$  using the primary key attributes.

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## ER to Relational Mapping

### Step #8: Convert Subclasses



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## Summary of ER to Relational Mapping

### ER Model

Entity Type  
1:1 or 1:N Relationship Type  
M:N Relationship Type  
 $n$ -ary Relationship Type  
Simple attribute  
Composite attribute  
Multi-valued attribute  
Key attribute

### Relational Model

Relation  
Foreign key (from N-side to 1-side)  
"Relationship" relation and 2 foreign keys  
"Relationship" relation and  $n$  foreign keys  
Attribute  
Set of simple component attributes  
Relation and foreign key  
Primary key attribute

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## ER to Relational Mapping Question

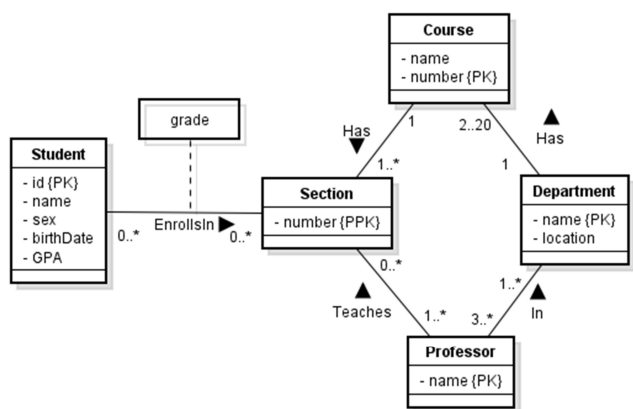
**Question:** How many of the following statements are **true**?

- 1) The M:N relationship mapping rule could be applied to 1:1 and 1:N relationships, as it is more general.
- 2) A weak entity will always have primary key attributes from the identifying entity.
- 3) The designer has a choice on which side to put the foreign key when mapping a 1:N relationship.
- 4) When mapping a multi-value attribute, the new table containing the multi-value attribute will have a composite key.

A) 0      B) 1      C) 2      D) 3      E) 4

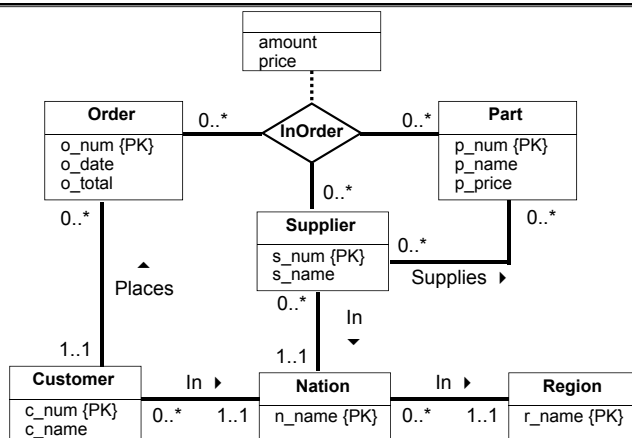
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## ER to Relational Mapping University Question



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## ER to Relational Mapping TPC-H Standard Question



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## Conclusion

There is a straightforward algorithm for converting ER models to relational schemas.

The algorithm involves 7 steps for converting regular ER models, and 8 steps for converting EER models.

In general, these steps convert entities to relations and ER relationships to relations. For 1:1 and 1:N relationships, foreign keys can be used instead of separate relations.

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## Objectives

Given an ER/EER diagram, be able to convert it into a relational schema using the seven/eight steps.

Be able to discuss the different ways of converting subclasses/superclasses into relational schemas.

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