Logical Schema Design: The Relational Data Model

Basics of the Relational Model

From Conceptual to Logical Schema

Logical Schema Design

- Select data model
  - Hierarchical data model: hierarchies of record types mainframe oldie, still in use, outdated
  - Network data model: graph like data structures, still in use, outdated
  - Relational data model: the most important one today
  - Object-Oriented data model: more flexible data structures, less powerful data manipulation language
  - Object-Relational: the best of two worlds?
- Transform conceptual model into logical schema of data model
  - easy for Relational Data Model (RDM)
  - can be performed automatically (e.g. by Oracle Designer)

Logical Schema Design: Relational Data Model

Important terms

- The Relational Data Model
  - 1970 introduced by E.F. Codd, honoured by Turing award
    (Codd: A Relational Model of Data for Large Shared Data Banks. ACM Comm. 13(6): 377- 387, 1970)
- Basic ideas:
  - Database is collection of relations
  - Relation R = set of n-tuples
  - Relation schema $R(A_1,A_2,\ldots A_n)$
  - Attributes A_i = atomic values of domain D_i=dom(A_i)

relation (table)

attribute

tuple

Student			
FName	Name	Email	SID
Tina	Müller	mueller@...	13555
Anna	Katz	katz@...	12555
Carla	Maus	piep@...	11222

relation schema: Student(Fname, Name, Email, SID) or
Student(Fname:string, Name:string, Email:string, SID:number)

Logical Schema Design: Relational Data Model

- Relation Schema $R(A_1, A_2, \ldots, A_n)$
  notation sometimes $R:\{[A_1, A_2, \ldots, A_n]\}$
- Relation $R \subseteq dom(A_1) \times dom(A_2) \times \ldots \times dom(A_n)$
- Attribute set $\mathcal{R} = \{A_1, A_2, \ldots, A_n\}$
- Degree of a relation: number of attributes
- Example:
  Student(Fname, Name, Email, SID)
  Student $\subseteq$ string x string x string x number
  $\mathcal{R}$ (Student) ={Fname, Name, Email, SID}
- Database Schema is set of relation schemas

Logical Schema Design: Relational Data Model

- Time-variant relations
  - Relations have state at each point in time.
  - Integrity constraints on state part of DB schema

- Tuples (rows, records)
  - Not ordered
  - No duplicate tuples (Relations are sets)
  - Null-values for some attributes possible
  - Distinguishable based on tuple values (key-concept)

    ↓

    Different to object identification in o-o languages:
    there, each object has implicit identity,
    usually completely unrelated to its fields

Logical Schema Design: Relational Data Model

Important terms

- Superkey:
  subset of attributes of a relation schema R for which no two tuples have the same value.

  - Every relation at least 1 superkey.
  - Example: Student(Fname, Name, Email, SID)
    Superkeys:
    {Fname, Name, Email, SID}, {Name, Email, SID},
    {Fname, Email, SID}, {Fname, Name, SID},
    {Fname, SID}, {Name, SID}, {Fname, Name, Email},
    {Fname, Email}, {Name, Email}, {Email, SID},
    {Email}, {SID}

Logical Schema Design: Relational Data Model

Important terms

- Candidate Key:
  superkey K of relation R such that if any attribute $A \in K$ is removed, the set of attributes $K \backslash A$ is not a superkey of R.
  - Example: Student(Fname, Name, Email, SID)
    Candidate Keys: {Email}, {SID}
- Primary Key:
  arbitrarily designated candidate key
  - Example: Student(Fname, Name, Email, <u>SID</u>)
    Primary Key: {SID}

Logical Schema Design: Relational Data Model

Important terms

- Foreign Key:
  set of attributes FK in relation schema R1 that references relation R2 if:
  - Attributes of FK have the same domain as the attributes of primary key K_2 of R_2
  - A value of FK in tuple t_1 in R_1 either occurs as a value of K_2 for some t_2 in R_2 or is null.
  - Example:
    R_1: Exercise(<u>EID</u>, Tutor, ExcerciseHours, Lecture)
    R_2: Student(Fname, Name, Email, <u>SID</u>)

    K_1={EID}, K_2={SID}
    Tutor is foreign key of Student (from Exercise).

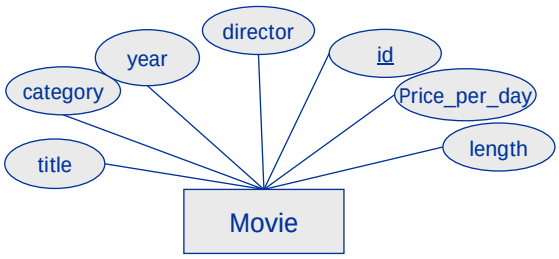
Logical Schema Design: Transformation

1. Select data model → relational data model
2. Transform conceptual model into logical schema of relational data model

- Define relational schema, table names, attributes and types, invariants
- Design steps:
  - Translate entities into relations
  - Translate relationships into relations
  - Simplify the design
  - Define tables in SQL
  - Define additional invariants
  - (Formal analysis of the schema)

Logical Schema Design: Entities

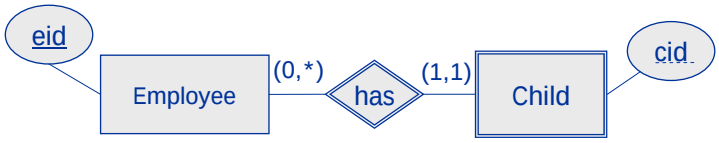
- Step 1: Transform entities
  - For each entity E create relation R with all attributes
  - Key attributes of E transform to keys of the relation



Relational Schema:
Movie(id, title, category, year, director, Price_per_day, length)

Logical Schema Design: Weak Entities

- Step 2: Transform weak entities
  - For each weak entity WE create relation R
  - Include all attributes of WE
  - Add key of identifying entity to weak entities key
  - Part of key is foreign key



Relational Schema:

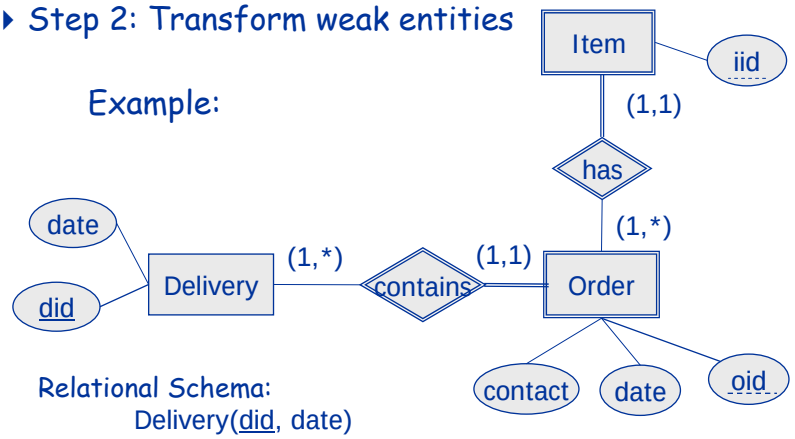
Employee(eid)
Child(cid, eid)

Note: weak entity and defining relationship transformed together!

Logical Schema Design: Weak Entities

- Step 2: Transform weak entities

Example:

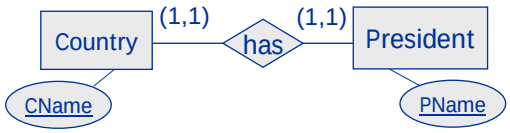


Relational Schema:

Delivery(did, date)
Order(oid, did, date, contact)
Item(iid, oid, did)

Logical Schema Design: Relationships

- Step 3: Transform Relationships
  - For each 1:1-relationship between E1, E2 create relation R
  - Include all key attributes
  - Define as key: key of entity E1 or entity E2
  - Choose entity with total participation for key (driving licence)

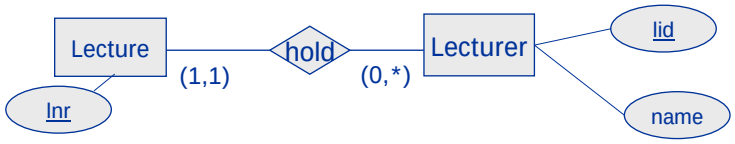


Relational Schema:

Country(CName)
President(PName)
has(CName, PName) or has(Cname, PName)

Logical Schema Design: Relationships

- Step 3: Transform Relationships
  - For each 1:N-relationship between E1, E2 create relation R
  - Include all key attributes
  - Define as key: key of N-side of relationship

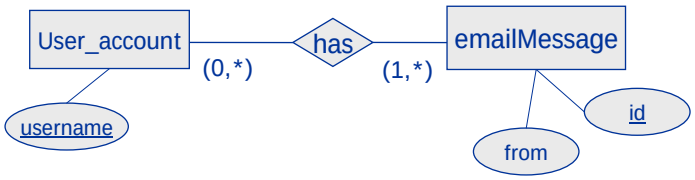


Relational Schema:

Lecture(lnr)
Lecturer(lid, name)
hold(lnr,lid)

Logical Schema Design: Relationships

- Step 3: Transform Relationships
  - For each N:M-relationship create relation R
  - Include all key attributes
  - Define as key: keys from both entities

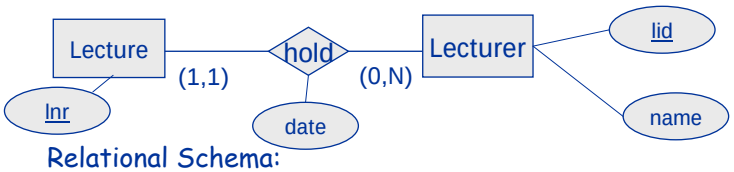


Relational Schema:

User_account(<u>username</u>)
emailMessage(<u>id</u>, from)
has(<u>username</u>, <u>messageid</u>)

Logical Schema Design: Relationships

- Step 3: Transform Relationships
  - Include all relationship attributes in relation R



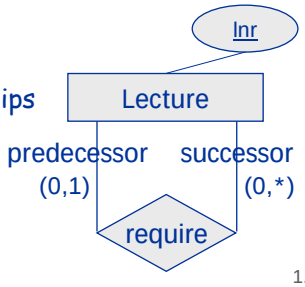
Relational Schema:

Lecture(<u>lnr</u>)
Lecturer(<u>lid</u>, name)
hold(<u>lnr</u>,lid, date)

- Rename keys in recursive relationships

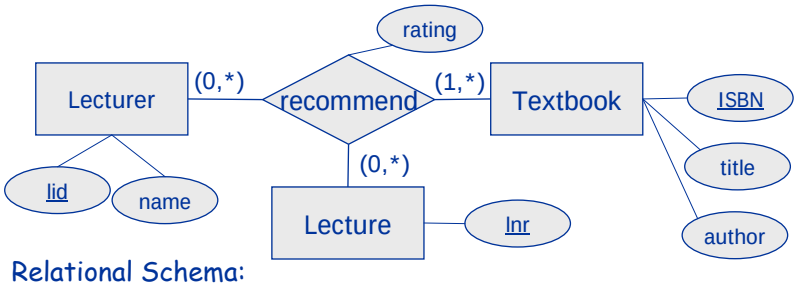
Relational Schema:

require(<u>preLNR</u>, succLNR)



Logical Schema Design: Relationships

- Step 3: Transform Relationships
  - For each n-ary relationship (n>2) create relation R
  - Include all key attributes
  - Define as key: keys from all numerously involved entities

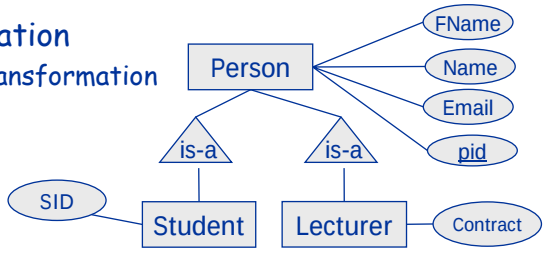


Relational Schema:

Lecture(lnr)
Lecturer(lid, name)
Textbook(ISBN, title, author)
recommend(lid, lnr, ISBN, rating)

Logical Schema Design: Generalization

- Step 4: Generalization
  - 3 Variants for Transformation



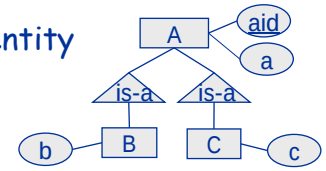
Person(pid, name, fname, email)
Student(pid, sid)
Lecturer(pid, contract)

Student(pid, name, fname, email, sid)
Lecturer(pid, name, fname, email, contract)

Person(pid, name, fname, email, sid, contract)

Logical Schema Design: Generalization

- (1) Separate relation for each entity
  - Key in specialized relations: foreign key to general relation

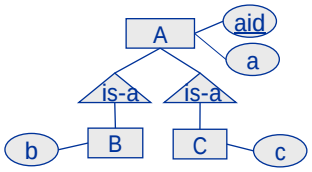


A(aid, a)
B(aid, b)
C(aid, c)

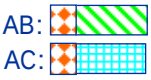
  - Gathering data from different tables time consuming
  - Appropriate specialization prevents unnecessary data access

Logical Schema Design: Generalization

- (2) Relations for specialization
  - Separate tables which include A's attributes
  - Separate keys for relations



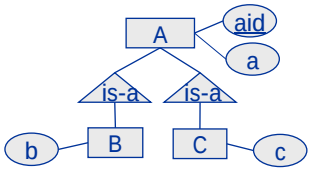
AB(aid, a, b)
AC(aid, a, c)



  - Only valid for exhaustive specialization (no data in A only)
  - Time consuming data retrieval for non-distinct specializations

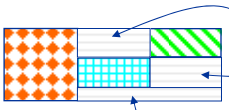
Logical Schema Design: Generalization

- (3) one relation for all entities



ABC(aid, a, b, c)

ABC:

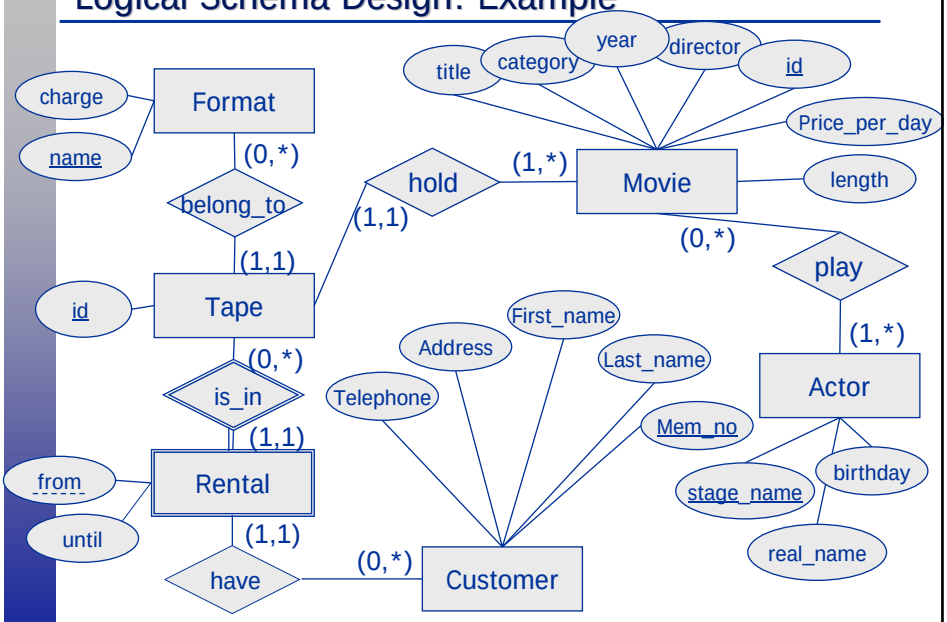


NULLs, if subtypes are disjoint

Empty, if subtypes are exhaustive

- Removes generalization!
- Relation may contain many NULL-values

Logical Schema Design: Example



Logical Schema Design: Example

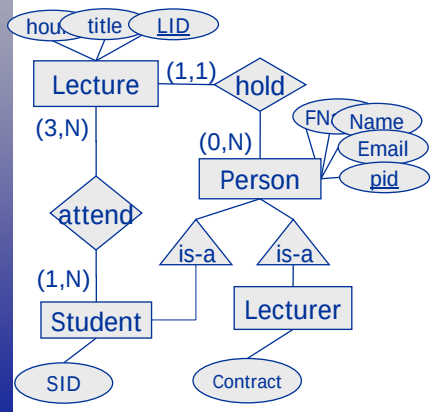
Format(name, charge)
Tape(id)
Movie(id, title, category, year, director, price_per_day, length)
Actor(stage_name, real_name, birthday)
Customer(mem_no, last_name, first_name, address, telephone)
Rental(tape_id, member, from, until)

Belong_to(formatname, tape_id)
Hold(tape_id, movie_id)
Play(movie_id, actor_name)

Reduce relation number by simplification!

Logical Schema Design: Simplification

- Collect those relation schemas with the same key attributes into one relation schema
  - Semantics of attributes must match, not literal name
  - Do not destroy generalization!



Lecture(lid, title, hours)
Person(pid, fname, name, email)
Student(pid, sid)
Lecturer(pid, contract)
Attend(lid, pid)
Hold(lid, pid)

Lecture(lid, title, hours, lecturer)

Logical Schema Design: Example

Format(name, charge)
Tape(id)
Movie(id, title, category, year, director, price_per_day, length)
Actor(stage_name, real_name, birthday)
Customer(mem_no, last_name, first_name, address, telephone)
Rental(tape_id, member, from, until)

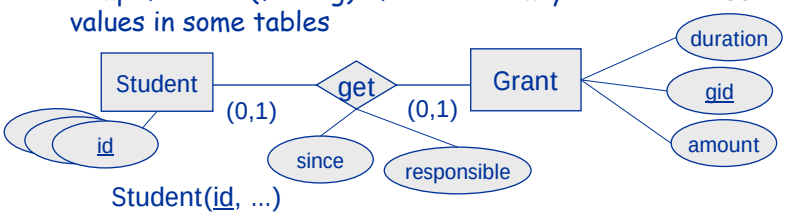
Belong_to(formatname, tape_id)
Hold(tape_id, movie_id)
Play(movie_id, actor_name)

Simplified relation from Tape/Belong_to/Hold:
Tape(id, format, movie_id)

No simplification based on partial keys!

Logical Schema Design: Simplification

- Restrictions on schema simplification
  - Simplification (folding) of relations may result in NULL values in some tables



Student(id, ...)
Grant(gid, duation, amount)
Get(student, gid, since, responsible)
Grant(gid, duation, amount, student, since, responsible)

Consequence:
- optional relationships should not be transformed if many NULLS to be expected
- May lead to time consuming retrieval

Logical Schema Design: Short summary

- Relational data model
  - Representation data in relations (tables)
  - the most important data model today
- Important terms & concepts
  - Relation: set of n-tuples
  - Relation schema defines structure
  - Attribute: property of relation, atomic values
  - Superkey, candidate key, primary key identify tuple
  - Transformation rules for entities, relationships
  - Simplification
- Open aspects of logical schema design
  - DDL for defining and changing relation schemas
  - Definition of constraints (Min-cardinalities, Value restrictions for attributes,…)