数据库设计与E-R模型

Database Design & E-R Model

李文根/Wengen Li

Email: lwengen@tongji.edu.cn

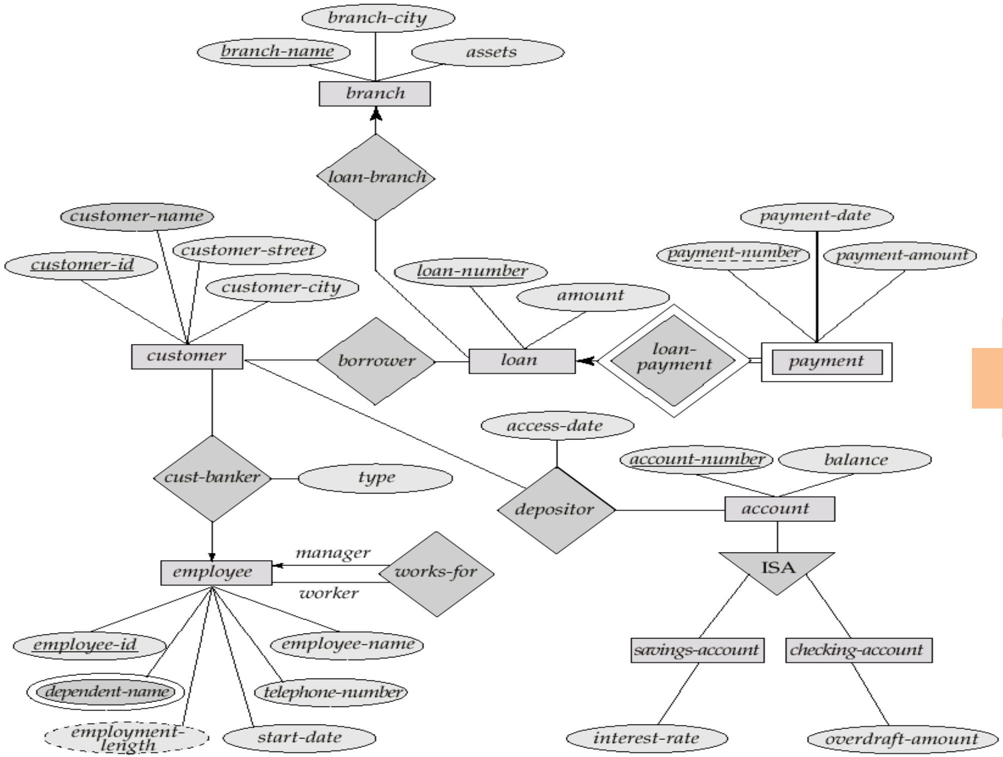
先进数据与机器智能系统实验室（ADMIS）
https://admis.tongji.edu.cn/main.htm

同濟大學 TONGJI UNIVERSITY | 电子与信息工程学院 College of Electronics and Information Engineering 计算机科学与技术系 Department of Computer Science and Technology

课程概要

- **Part 0: Overview**
  - Ch1: Introduction
- **Part 1 Relational Databases**
  - Ch2: Relational model
  - Ch3: Introduction to SQL
  - Ch4: Intermediate SQL
  - Ch5: Advanced SQL
- **Part 2 Database Design**
  - **Ch6: Database design based on E-R model**
  - Ch7: Relational database design
- **Part 3 Application Design & Development**
  - Ch8: Complex data types
  - Ch9: Application development
- **Part 4 Big data analytics**
  - Ch10: Big data
  - Ch11: Data analytics
- **Part 5 Data Storage & Indexing**
  - Ch12: Physical storage system
  - Ch13: Data storage structure
  - Ch14: Indexing
- **Part 6 Query Processing & Optimization**
  - Ch15: Query processing
  - Ch16: Query optimization
- **Part 7 Transaction Management**
  - Ch17: Transactions
  - Ch18: Concurrency control
  - Ch19: Recovery system
- **Part 8 Parallel & Distributed Database**
  - Ch20: Database system architecture
  - Ch21-23: Parallel & distributed storage, query processing & transaction processing
- **Part 9**
  - DB Platform: **OceanBase**, MongoDB, Neo4J

E-R图和关系模式(Banking DB)



E-R图

- *branch (branch_name, branch_city, assets)*
- *customer (customer_id, customer_name, customer_street, customer_city)*
- *loan (loan_number, amount)*
- *account (account_number, balance)*
- *employee (employee_id, employee_name, telephone_number, start_date)*

- *dependent_name (employee_id, dname)* (derived from a multivalued attribute)

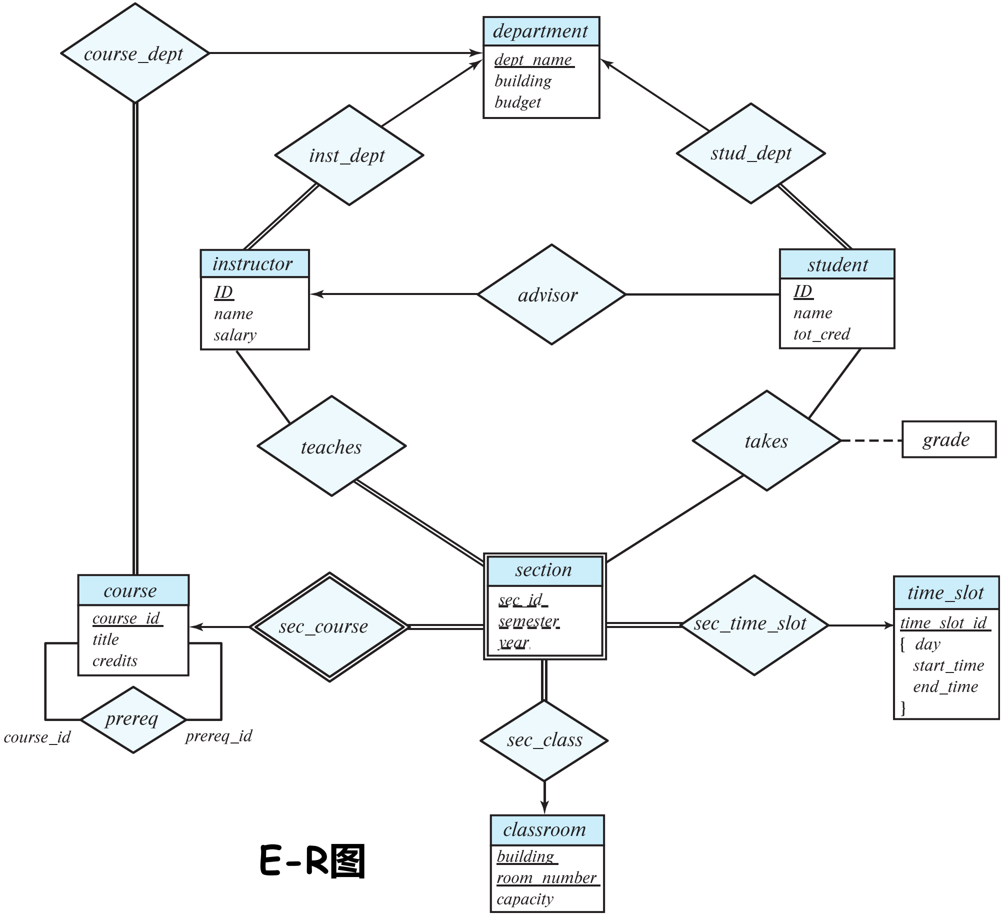
- *account_branch (account_number, branch_name)*
- *loan_branch (loan_number, branch_name)*
- *borrower (customer_id, loan_number)*
- *depositor (customer_id, account_number, access_date)*
- *cust_banker (customer_id, employee_id, type)*
- *works_for (worker_employee_id, manager_employee_id)*

- *Payment (loan_number, payment_number, payment_date, payment_amount)*

- *savings_account (account_number, interest_rate)*
- *checking_account (account_number, overdraft_amount)*

关系模式

E-R图和关系模式(University DB)



E-R图

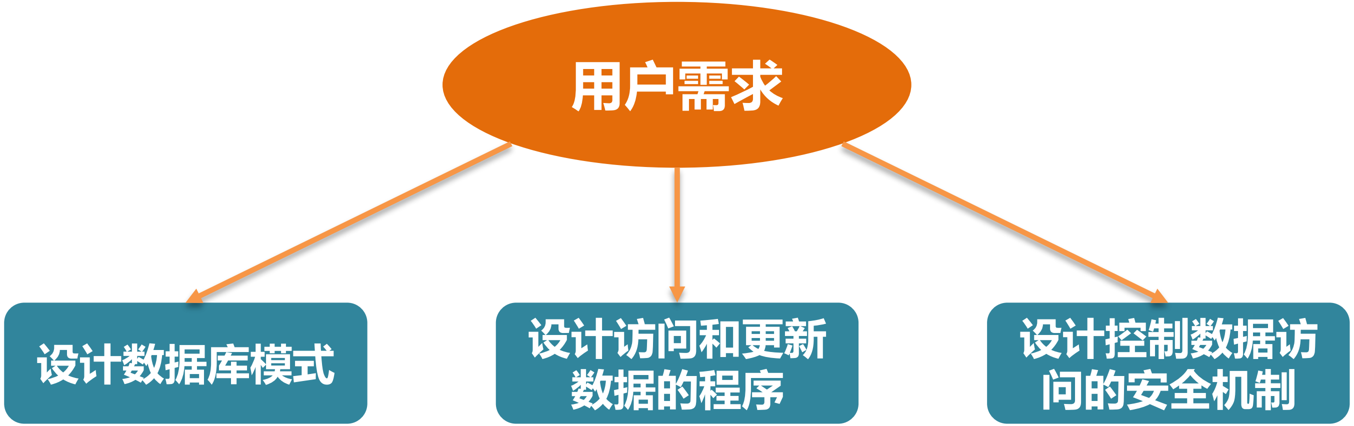
classroom(building, room_number, capacity)
department(dept_name, building, budget)
course(course_id, title, credits)
instructor(ID, name, salary)
student(ID, name, tot_cred)
teaches (ID, course_id, sec_id, semester, year)
takes (ID, course_id, sec_id, semester, year, grade)
prereq (course_id, prereq_id)
advisor (s_ID, i_ID)
sec_course (course_id, sec_id, semester, year)
sec_time_slot (course_id, sec_id, semester, year, time_slot_id)
sec_class (course_id, sec_id, semester, year, building, room_number)
inst_dept (ID, dept_name)
stud_dept (ID, dept_name)
course_dept (course_id, dept_name)

关系模式

目录

- 设计过程概览
- E-R模型
- 约束
- E-R图
- E-R图转换为关系模式

开发数据库应用的主要任务



用户需求

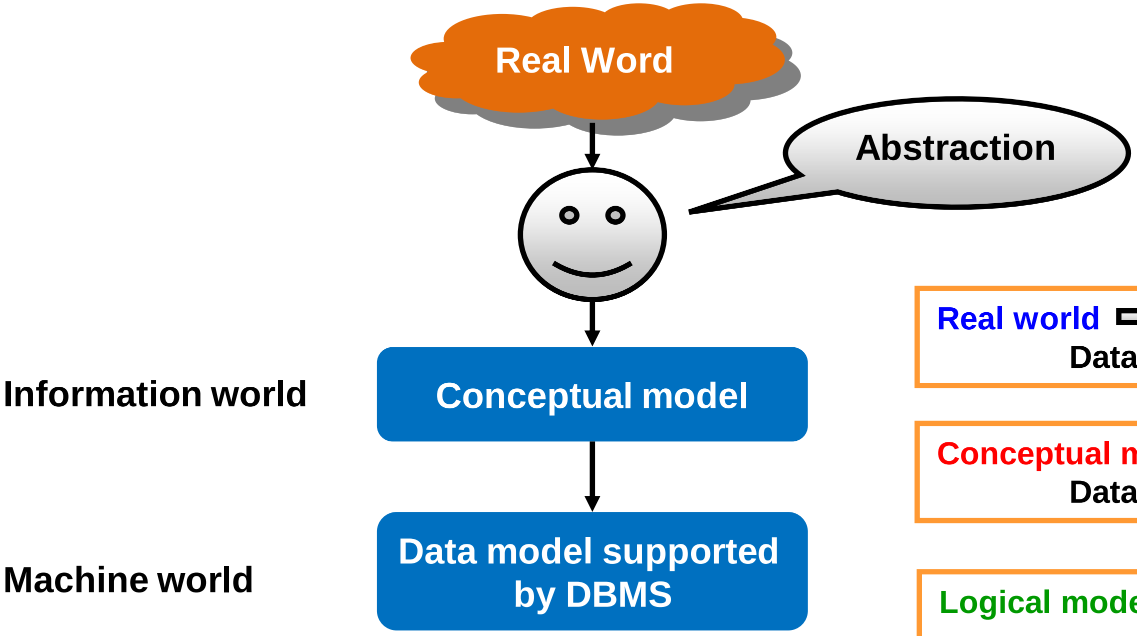
设计数据库模式

设计访问和更新数据的程序

设计控制数据访问的安全机制

- 关系（表）
- 关系的属性
- 约束

数据抽象(Data Abstraction)



Real world ⇨ Conceptual model
Database Designers

Conceptual model ⇨ Logical model
Database Designers

Logical model ⇨ Physical model
DBMS

数据库设计(Database Design)

- **Conceptual design(概念设计)**
  - Map a real world organization to a conceptual model
- **Logical design(逻辑设计)**
  - Transform the conceptual model to a logical model
- **Physical design(物理设计)**
  - Instantiate the logical model to physical organization and storage

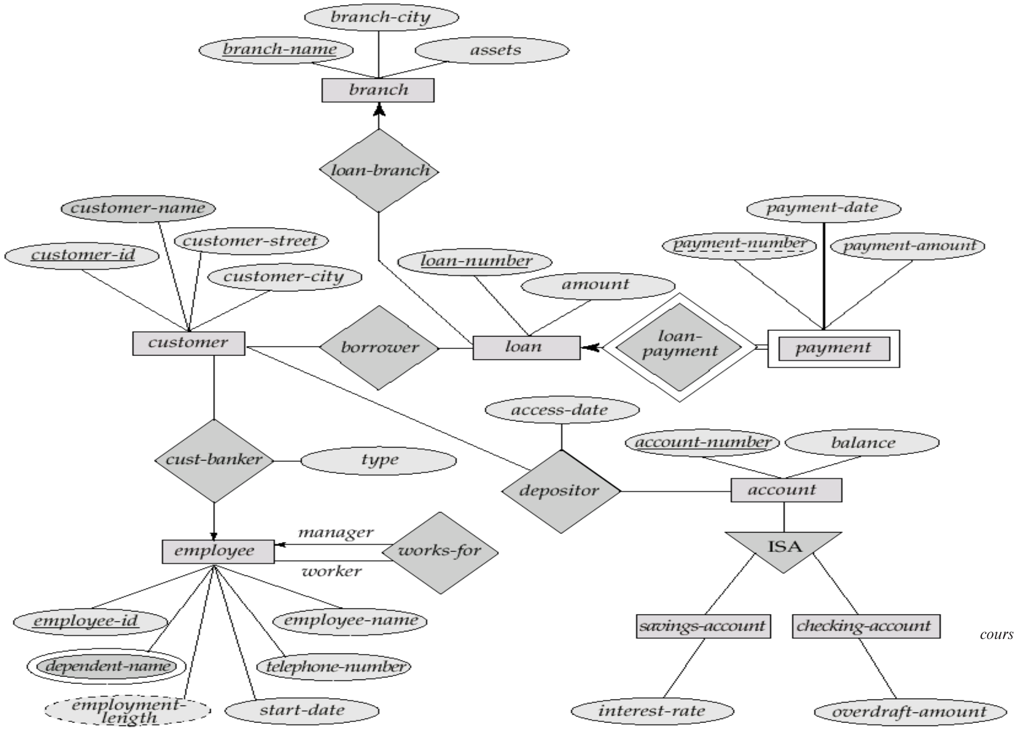
数据库设计(续)

- 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
    - Entity-Relationship (E-R) model
    - Object Definition Language (ODL)
- Translate specification to the data model of DBMS
  - Relational, XML, object-oriented, etc.
- Create the DBMS schema

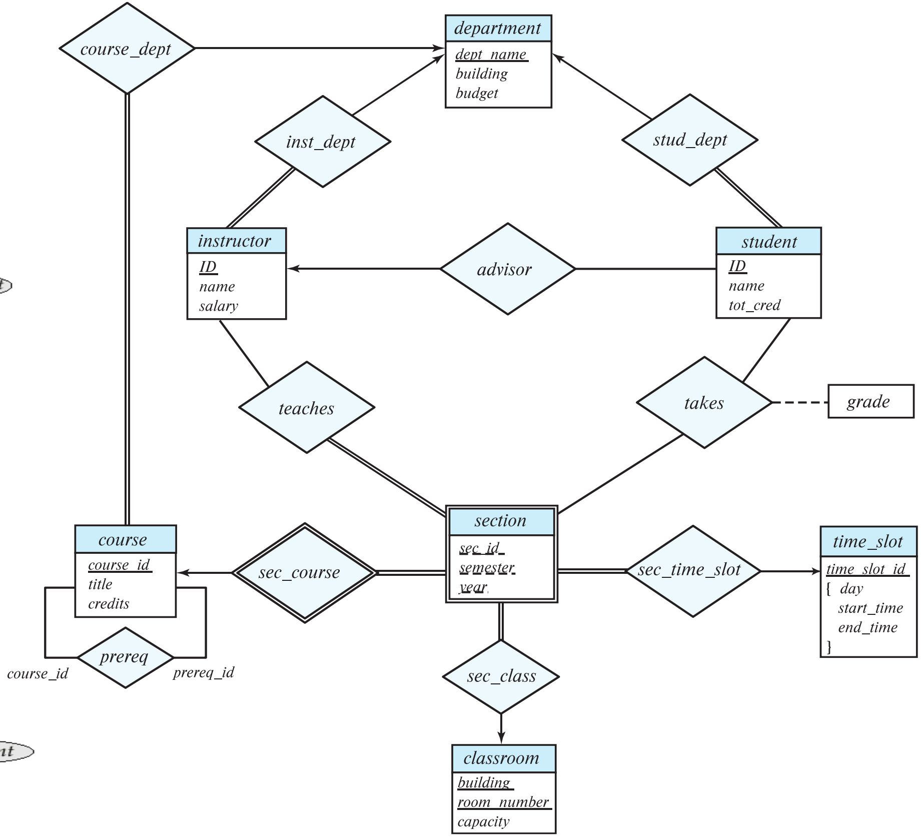
目录

- 设计过程概览
- E-R模型
- 约束
- E-R图
- E-R图转换为关系模式

E-R Diagram



Banking DB



University DB

数据库概念设计(Database Conceptual Design)

- **Conceptual design (E-R Model is used at this stage)**
  - **What** are the entities and relationships?
  - **What** information about these entities and relationships should be stored in the database?
  - **What** are the integrity constraints or business rules that should hold?

  - A database ‘schema’ in the E-R Model can be represented pictorially using **E-R diagram**
  - An E-R diagram can be then mapped into a relational schema

E-R模型

- A “watered-down” object-oriented design model
- Primarily a design model—not implemented by any major DBMS
- **Three concepts**
  - Entity set
  - Attribute
  - Relationship set

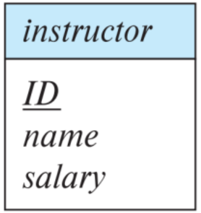
Peter Pin-Shan Chen（陈品山）

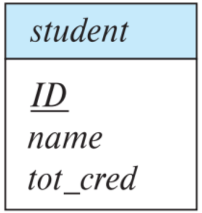
- Dr. Peter P. Chen is the originator of the Entity-Relationship Model (E-R Model), and the founder of ER international conference
- The E-R model serves as the foundation of many system analysis and design methodologies, computer-aided software engineering (CASE) tools, and repository systems

Peter Chen, ***The Entity-Relationship Model--Toward a Unified View of Data***
ACM Transactions on Database Systems, Vol. 1, No. 1, March 1976, Pages 9 - 36

Entity Sets（实体集）

- **A database can be modeled as**
  - a collection of entities
  - relationship among entities
- An entity is an object that exists and is distinguishable from other objects
  - E.g., specific person, company, event, university
- Entities have attributes
  - E.g., people have names and addresses
- An entity set is a set of entities of the same type that share the same properties
  - E.g., the set of all persons, companies, trees, holidays





实体集(续)

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

instructor

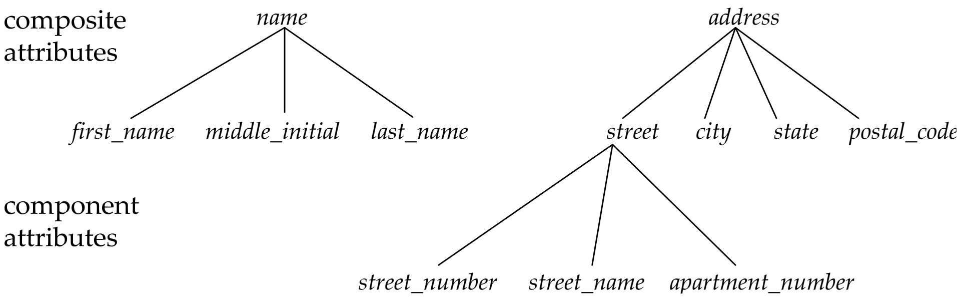
98988	Tanaka
12345	Shankar
00128	Zhang
76543	Brown
76653	Aoi
23121	Chavez
44553	Peltier

student

属性(Attributes)

- An entity contains a set of attributes, and these attributes are possessed by all members of an entity set
  - ***Instructor****: ID, name, salary*
  - ***Student****: ID, name, tot_cred*
- Domain (域) – the set of permitted values for each attribute

- **Attribute types**
  - Simple and composite attributes (复合属性)
  - Single-valued and multi-valued attributes
  - Derived attributes (派生属性)



instructor

- *ID*
- *name*
  - *first_name*
  - *middle_initial*
  - *last_name*
- *address*
  - *street*
    - *street_number*
    - *street_name*
    - *apt_number*
  - *city*
  - *state*
  - *zip*
- *{ phone_number }*
- *date_of_birth*
- *age ( )*

联系集(Relationship Sets)

- A relationship is an association among several entities
  - E.g.,

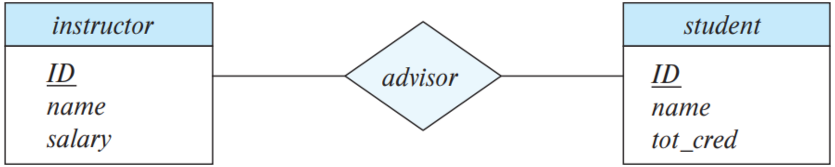
44553 (Peltier) *advisor* *22222 (Einstein)*

student entity *relationship set* *instructor entity*

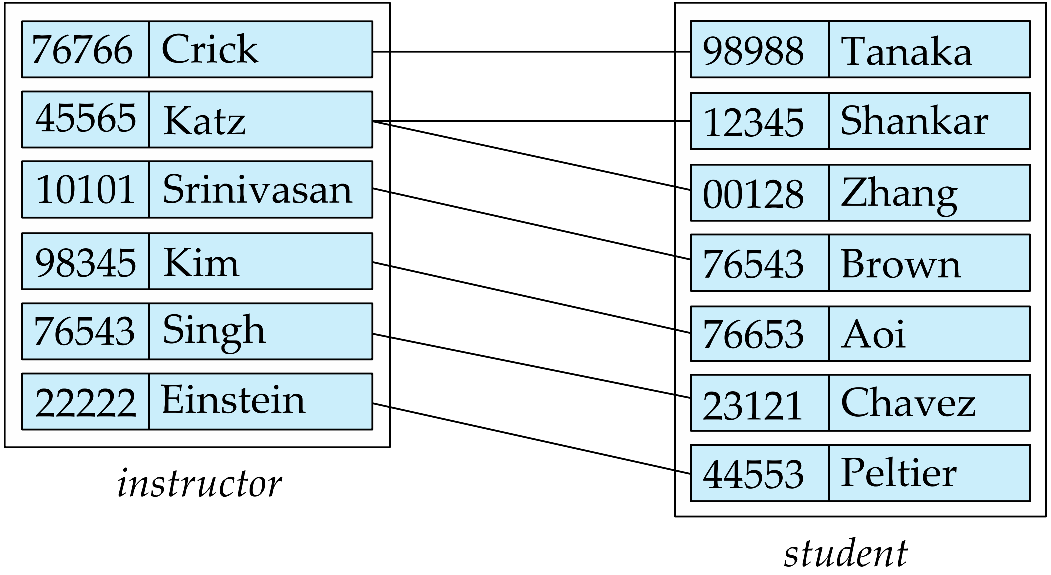
- A relationship set is a mathematical relation among $n \geq 2$ entities, each taken from entity sets

$$\{(e_1, e_2, \dots, e_n) | e_1 \in E_1, e_2 \in E_2, \dots, e_n \in E_n\}$$

where $(e_1, e_2, \dots, e_n)$ is a relationship, e.g., (44553,22222) ∈ advisor



联系集advisor



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

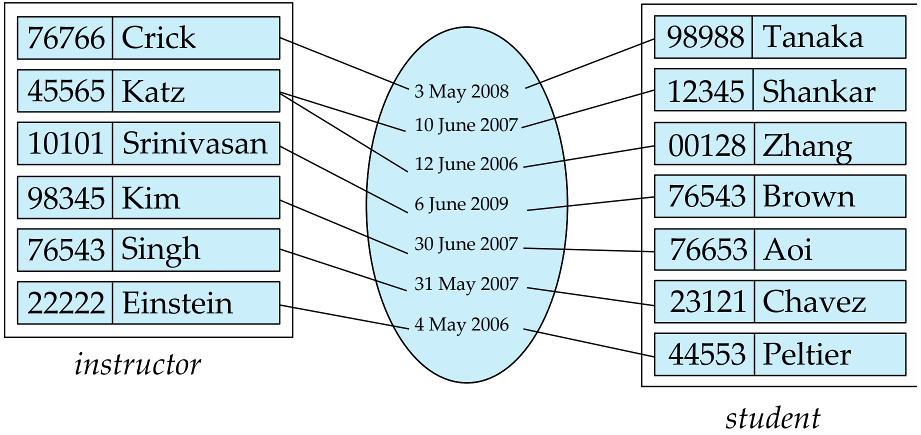
instructor

98988	Tanaka
12345	Shankar
00128	Zhang
76543	Brown
76653	Aoi
23121	Chavez
44553	Peltier

student

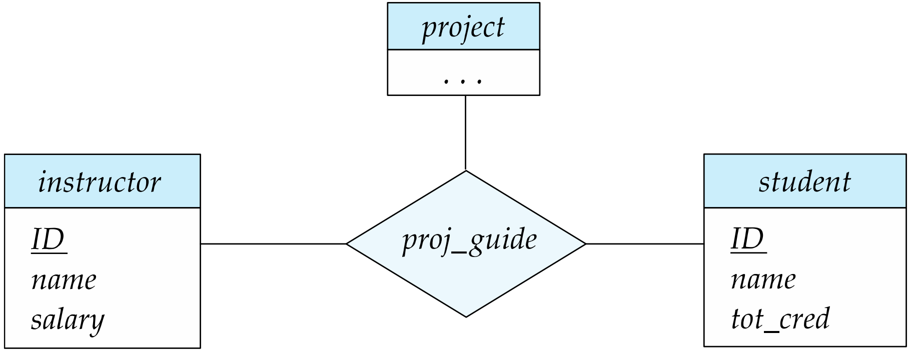
联系集（续）

- A relationship set may also contain some attributes
- 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



Degree (度/阶) of a Relationship Set

- **The number of entity sets that participate in a relationship set**
  - Relationship sets that involve two entity sets are binary (二元的)
  - Relationship sets may involve more than two entity sets, which is rare
    - E.g., E-R diagram with a ternary relationship (三元联系)

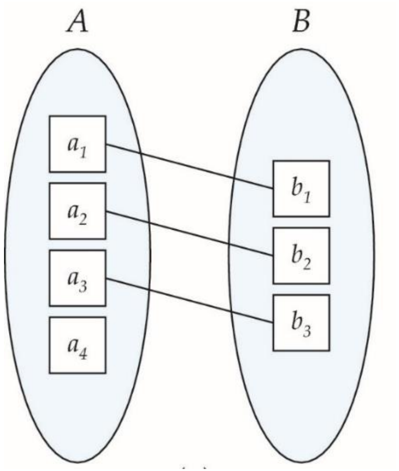


目录

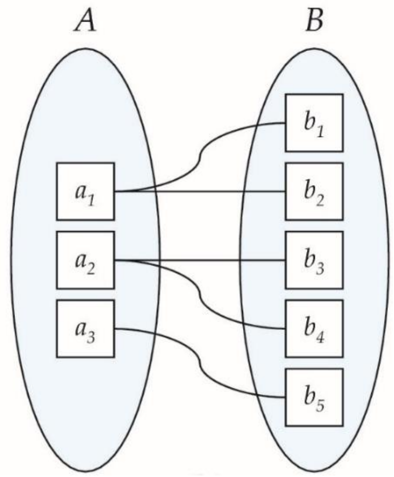
- 设计过程概览
- E-R模型
- 约束
- E-R图
- E-R图转换为关系模式

Mapping Cardinalities (映射基数)

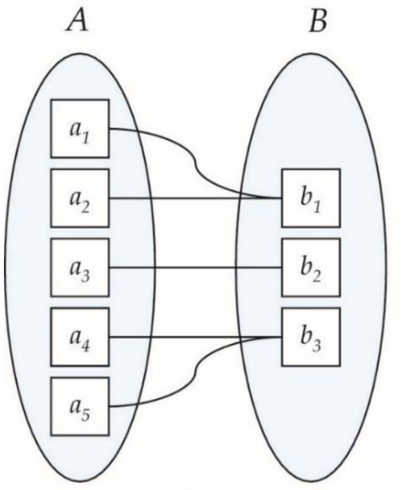
- 一个实体通过关系集可以关联的实体数量
- 给定两个实体集A和B：



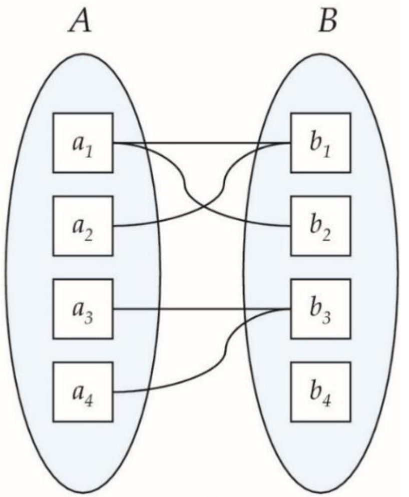
一对一



一对多



多对一



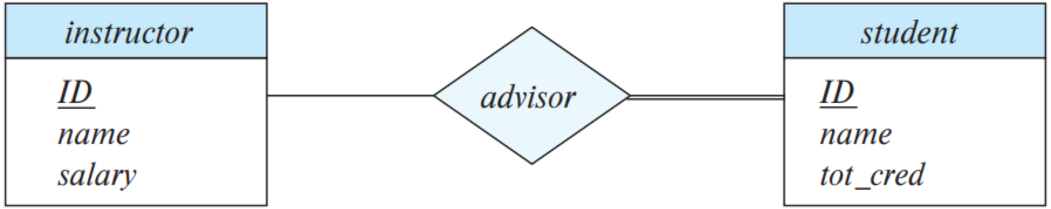
多对多

映射基数(续)

- Express the number of entities to which another entity can be associated via a relationship set
- For a binary relationship set, the mapping cardinality is one of the following types
  - **One to one (1对1):** An entity in A is associated with at most one entity in B, and an entity in B is associated with at most one entity in A
  - **One to many (1对多):** An entity in A is associated with any number (zero or more) of entities in B. An entity in B, however, can be associated with at most one entity in A
  - **Many to one (多对1):** An entity in A is associated with at most one entity in B. An entity in B, however, can be associated with any number (zero or more) of entities in A
  - **Many to many (多对多):** An entity in A is associated with any number (zero or more) of entities in B, and an entity in B is associated with any number (zero or more) of entities in A

参与约束(Participation Constraints)

- **Total participation**
  - Every entity in the entity set participates in at least one relationship in the relationship set
  - E.g., 每个student实体通过advisor联系同至少一名教师关联，student在联系集advisor中是全部参与
- **Partial participation**
  - Some entities may not participate in any relationship in the relationship set
  - E.g., 有的instructor可能不指导学生，所以instructor在联系集advisor中是部分参与

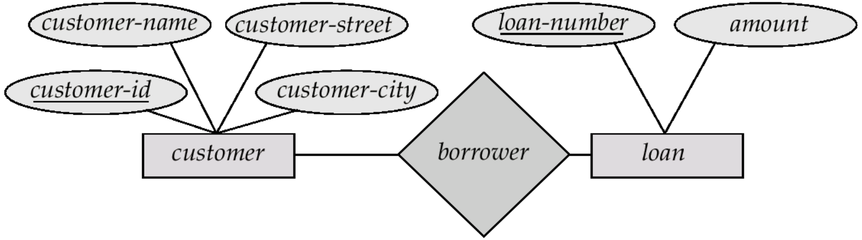


目录

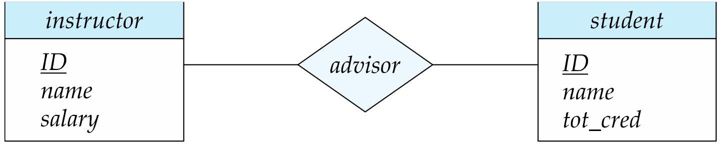
- 设计过程概览
- E-R模型
- 约束
- E-R图
- E-R图转换为关系模式

E-R图

- Rectangles represent entity sets
- Diamonds represent relationship sets.
- Lines link attributes to entity sets and entity sets to relationship sets.
- Ellipses represent attributes
  - Double ellipses represent multi-valued attributes
  - Dashed ellipses denote derived attributes
- Underline indicates primary key attributes

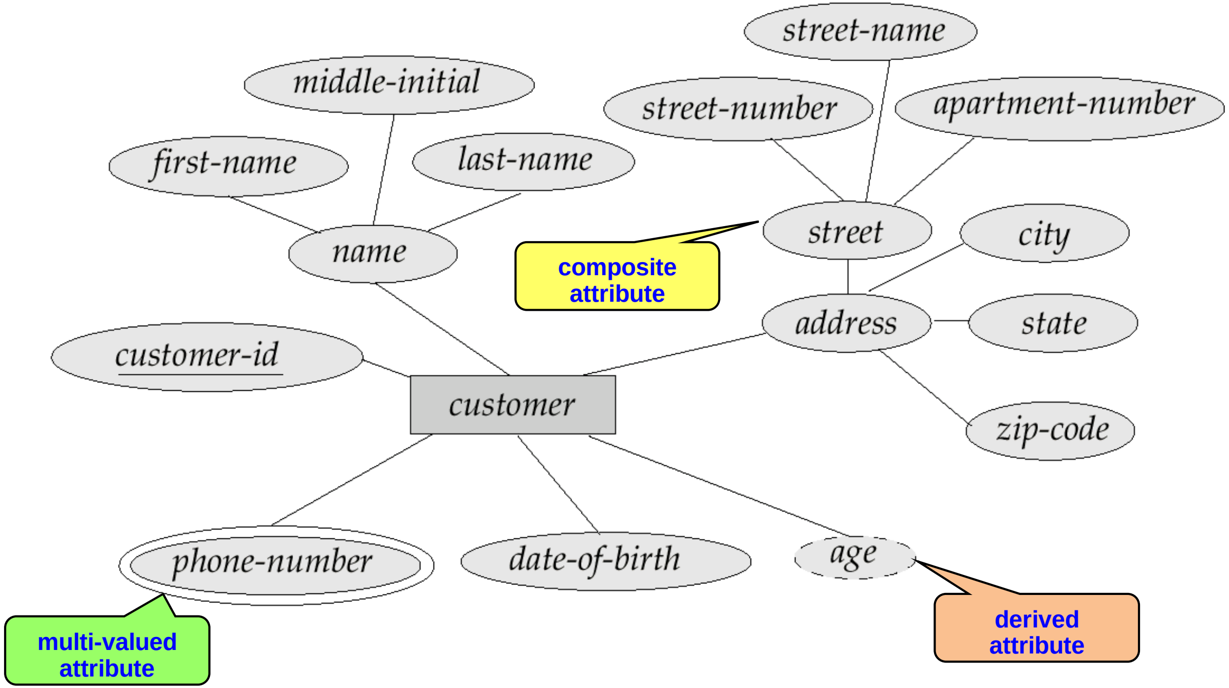


- Entity sets can be represented graphically as follows:
  - Rectangles represent entity sets.
  - Attributes listed inside entity rectangle
  - Underline indicates primary key attributes
- Diamonds represent relationship sets



E-R图(续)

- E-R diagram with composite, multivalued, and derived attributes



composite attribute

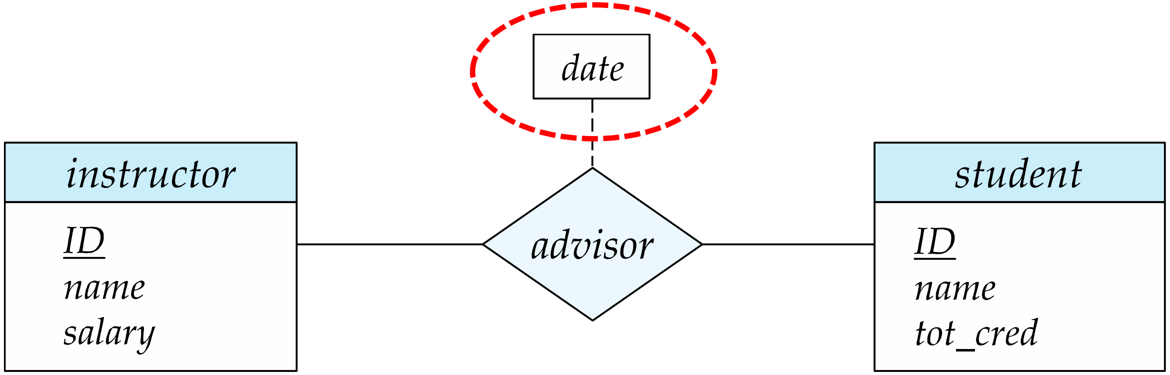
multi-valued attribute

derived attribute

instructor

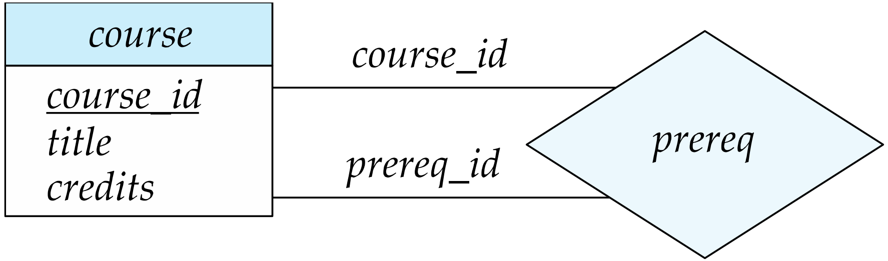
ID
- *name*
  - *first_name*
  - *middle_initial*
  - *last_name*
- *address*
  - *street*
    - *street_number*
    - *street_name*
    - *apt_number*
  - *city*
  - *state*
  - *zip*
- *{ phone_number }*
- *date_of_birth*
- *age ( )*

Relationship Sets with Attributes



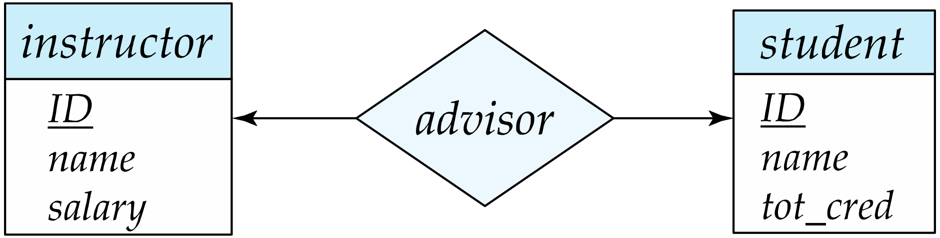
Roles (角色)

- **Entity sets of a relationship need not be distinct**
  - Each occurrence of an entity set plays a “role” in the relationship
  - The labels “course_id” and “prereq_id” are called **roles**



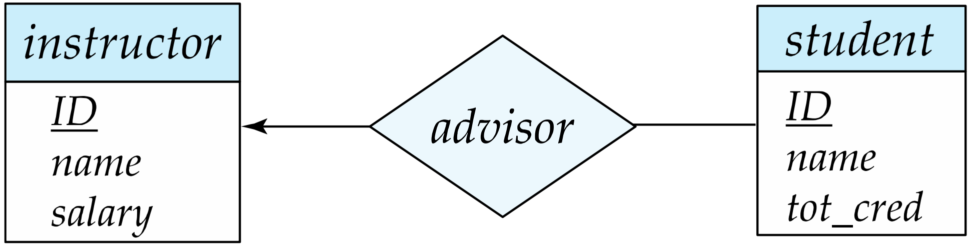
Cardinality Constraints

- We express cardinality constraints by drawing either a directed line (→), signifying “one,” or an undirected line (—), signifying “many,” between the relationship set and the entity set.
- **One-to-one relationship**
  - A student is associated with at most one instructor via the relationship advisor, and vice versa



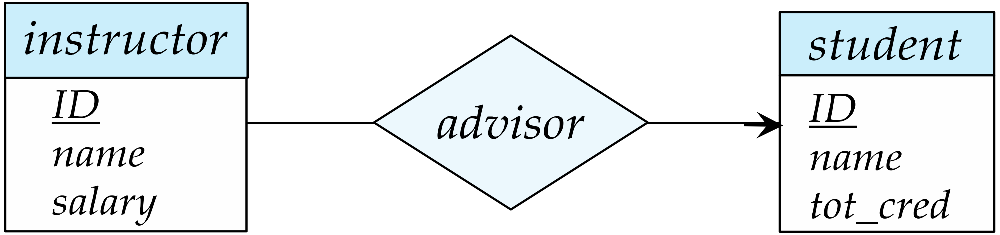
One-To-Many Relationship

- **One-to-many relationship**
  - an instructor is associated with several (including 0) students via advisor
  - a student is associated with at most one instructor via advisor



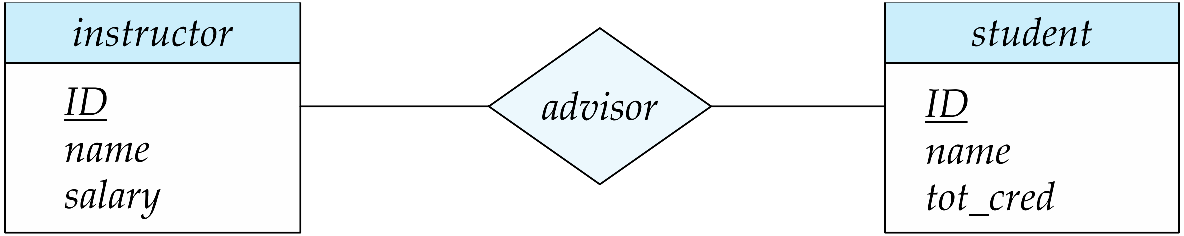
Many-To-One Relationships

- **Many-to-one relationship**
  - an instructor is associated with at most one student via advisor
  - a student is associated with several (including 0) instructors via advisor



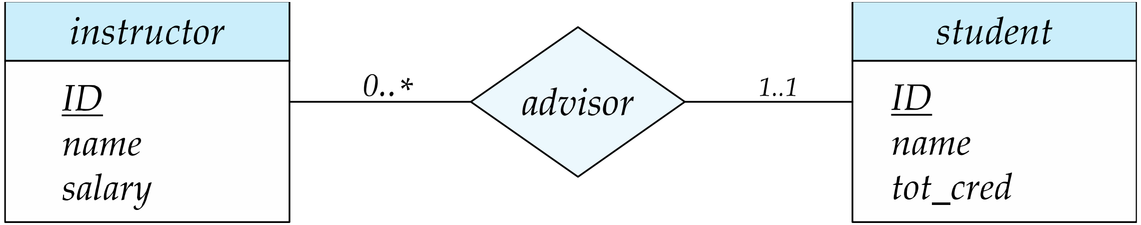
Many-To-Many Relationship

- **Many-to-many relationship**
  - An instructor is associated with several (possibly 0) students via advisor
  - A student is associated with several (possibly 0) instructors via advisor



Alternative Notation for Cardinality Limits

- A line may have an associated minimum and maximum cardinality, shown in the form l…h, where l is the minimum and h the maximum cardinality
  - A minimum value of 1 indicates total participation
  - A maximum value of 1 indicates that the entity participates in at most one relationship
  - A maximum value of * indicates no limit
- **Example**
  - Instructor can advise 0 or more students. A student must have 1 advisor and cannot have multiple advisors



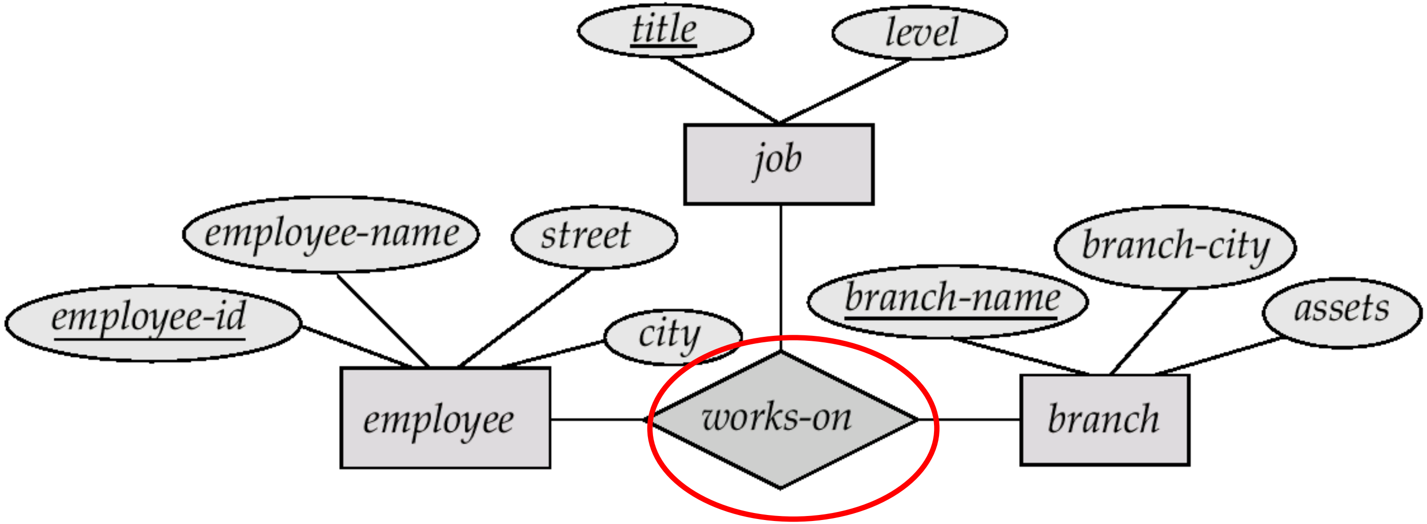
Keys (键/码)

- A superkey (超键) of an entity set is a set of one or more attributes whose values uniquely determine each entity
- A candidate key (候选键) of an entity set is a **minimal superkey**
  - student_id is a candidate key of student
  - account_number is a candidate key of account
- Although several candidate keys may exist, one of the candidate keys is selected to be the primary key (主键)

Keys for Relationship Sets

- The **combination of primary keys** of the participating entity sets forms a superkey of a relationship set
  - (customer_id, account_number) is the super key of depositor
- Must consider the mapping cardinality of the relationship set when deciding the candidate keys
- Need to consider the semantics of relationship set in selecting the primary key in case of more than one candidate key

E-R Diagram with a Ternary Relationship

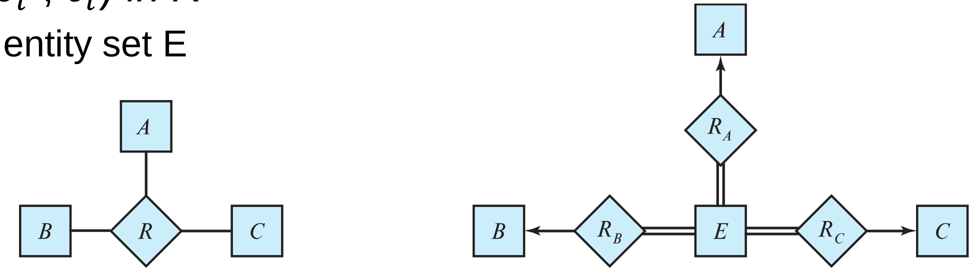


Binary vs. Non-Binary Relationships

- Some relationships that appear to be non-binary may be better represented using binary relationships
  - E.g. A ternary relationship parents, relating a child to his/her father and mother, can be replaced by two binary relationships, father and mother
    - Using two binary relationships allows partial information (e.g., only mother being known)
  - But there are some relationships that are naturally non-binary
    - E.g. works-on, proj_guide

Converting Non-Binary Relationships

- Any non-binary relationship can be represented using binary relationships by creating an **artificial entity set**
  - Replace R between entity sets A, B and C with an entity set E, and three relationship sets:
    - R_A, relating E and A
    - R_B, relating E and B
    - R_C, relating E and C
  - Create a special identifying attribute for E, and add any attributes of R to E
  - For each relationship $(a_i\ , b_i\ , c_i)$ in R
    - add a new entity e_i in the entity set E
    - add (e_i, a_i) to R_A
    - add (e_i, b_i) to R_B
    - add (e_i, c_i) to R_C

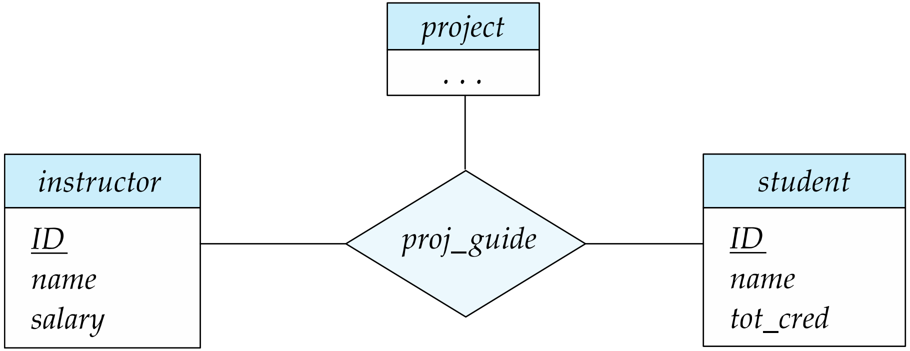


(a)

(b)

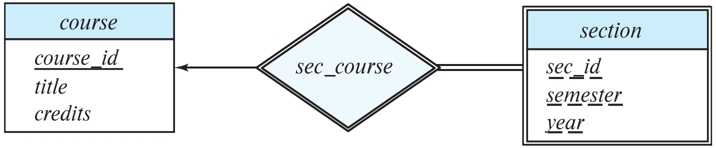
Converting Non-Binary Relationships (Cont.)

- **Translate constraints**
  - Translating all constraints may not be possible
  - There may be instances in the translated schema that cannot correspond to any instance of R
  - We can avoid creating an identifying attribute by making E a weak entity set (described shortly) identified by the three relationship sets



Weak Entity Sets（弱实体集）

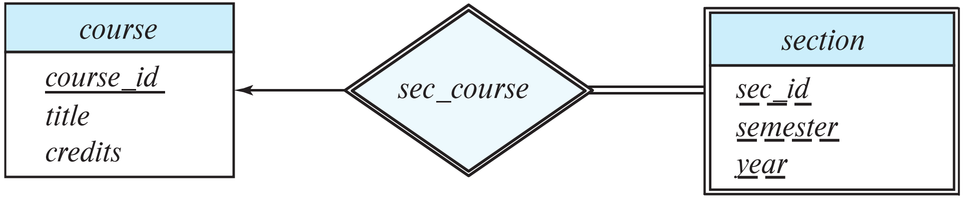
- **Entity set section**
  - uniquely identified by a course_id, semester, year, and sec_id.
  - related to course entities



- **Relationshit set sec_course between entity sets section and course**
  - the information in sec_course is redundant, since section already has an attribute course_id, which identifies the course with which the section is related
  - **Solution A**: Get rid of the relationship sec_course. However, by doing so the relationship between section and course becomes implicit in an attribute, which is not desirable
  - **Solution B**: Not store the attribute course_id in the section entity and only store the remaining attributes section_id, year, and semester. However, the entity set section then does not have enough attributes to identify a particular section entity uniquely
- **Way out**
  - Treat sec_course as **a special relationship** that provides extra information, the course_id, required to identify section entities uniquely
  - A **weak entity set** is one whose existence is dependent on another entity, called its identifying entity (标识性实体)
  - Instead of associating a primary key with a weak entity, we use the identifying entity, along with extra attributes called discriminator (分辨符) to uniquely identify a weak entity

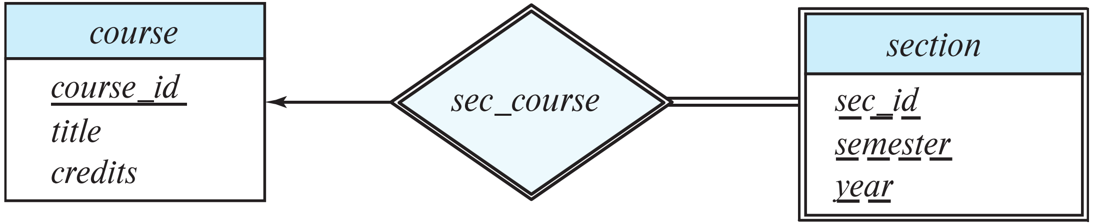
Weak Entity Sets（Cont.)

- **Strong entity set**
  - An entity set that is not a weak entity set is termed a strong entity set.
- **Weak entity set & identifying entity**
  - Every weak entity must be associated with an identifying entity. The weak entity set is said to be existence dependent on the identifying entity set (**标识性实体集**).
  - The identifying entity set is said to own the weak entity set that it identifies.
  - The relationship associating the weak entity set with the identifying entity set is called the identifying relationship (**标识性联系**)



Weak Entity Sets (Cont.)

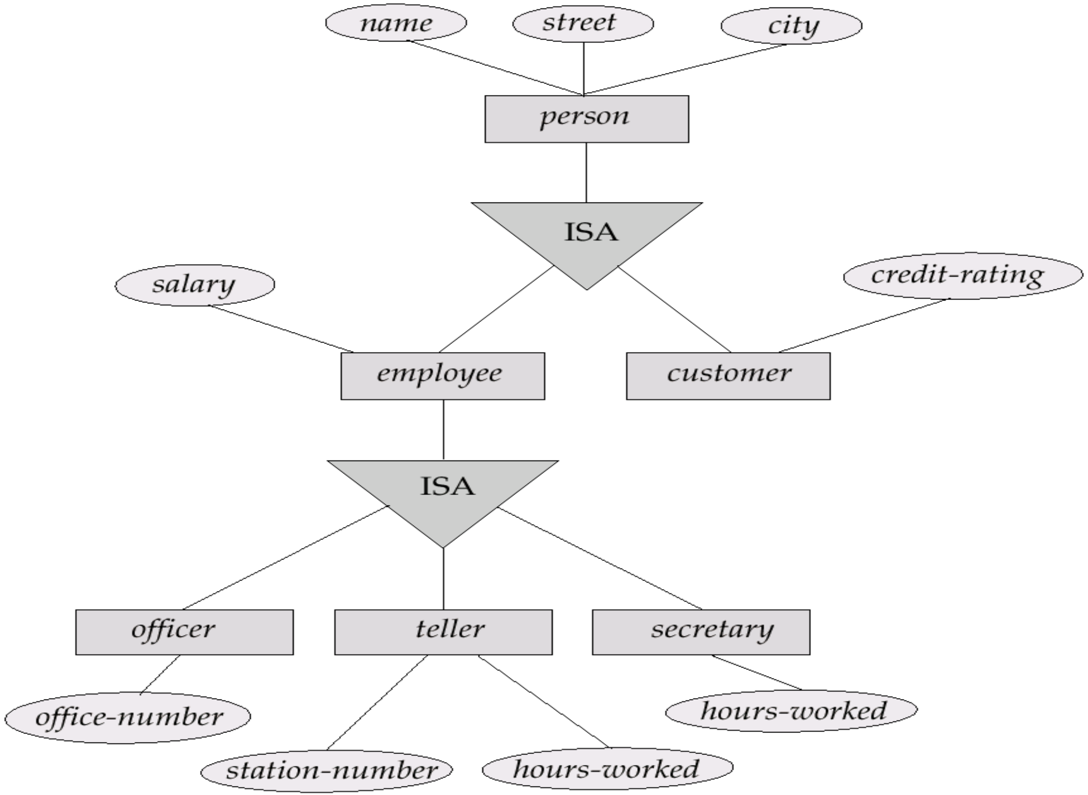
- In E-R diagrams, a weak entity set is depicted via a double rectangle
- The discriminator of a weak entity set is underlined with a dashed line
- The relationship set connecting the weak entity set to the identifying strong entity set is depicted by a double diamond
- Primary key for section – (**course_id**, sec_id, semester, year)



Specialization（特化）

- **自上而下的设计过程**
  - Designate subgroupings within an entity set that are distinctive from other entities in the set
  - These subgroupings become lower-level entity sets that have attributes or participate in relationships that do not apply to the higher-level entity set.
  - Depicted by a triangle component labeled ISA, e.g., customer “is a” person
- **Attribute inheritance（属性继承）**
  - A lower-level entity set inherits all the attributes and relationship participation of the higher-level entity set to which it is linked

Example


name
street
city
person
ISA
salary
credit-rating
employee
customer
ISA
officer
teller
secretary
office-number
station-number
hours-worked
hours-worked

Generalization（泛化）

- **自下而上的设计过程**
  - Combine a number of entity sets that share the same features into a higher-level entity set
- **特化与泛化**
  - Specialization and generalization are inversions of each other
  - They are represented in the same way in an E-R diagram

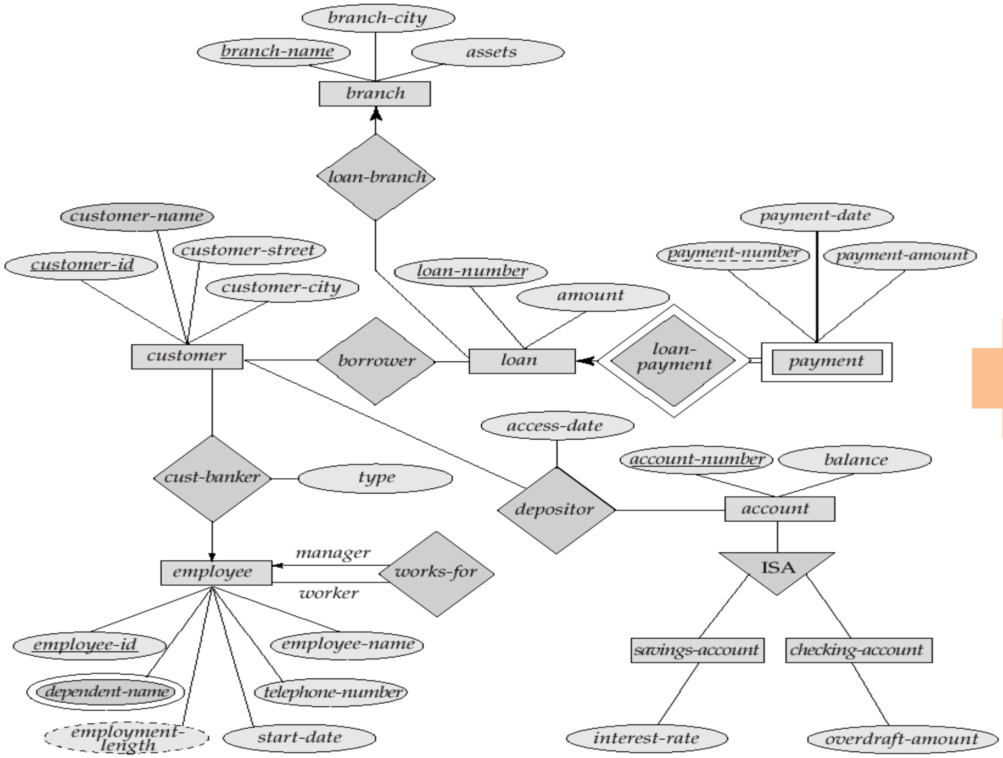
Specialization & Generalization (Cont.)

- One entity set may have multiple specializations based on different features
  - E.g., permanent-employee vs. temporary-employee, officer vs. secretary vs. teller
  - Each particular employee would be
    - a member of one of permanent-employee or temporary-employee, and
    - a member of one of officer, secretary or teller
- The ISA relationship also referred to as superclass - subclass relationship

目录

- 设计过程概览
- E-R模型
- 约束
- E-R图
- E-R图转换为关系模式

Reduction to Relation Schemas



E-R图

- *branch = (branch_name, branch_city, assets)*
- *customer = (customer_id, customer_name, customer_street, customer_city)*
- *loan = (loan_number, amount)*
- *account = (account_number, balance)*
- *employee = (employee_id, employee_name, telephone_number, start_date)*

- *dependent_name = (employee_id, dname)* (derived from a multivalued attribute)

- *account_branch = (account_number, branch_name)*
- *loan_branch = (loan_number, branch_name)*
- *borrower = (customer_id, loan_number)*
- *depositor = (customer_id, account_number, access_date)*
- *cust_banker = (customer_id, employee_id, type)*
- *works_for = (worker_employee_id, manager_employee_id)*

- *payment =(loan_number, payment_number,*
- *payment_date, payment_amount)*

- *savings_account = (account_number, interest_rate)*
- *checking_account = (account_number, overdraft_amount)*

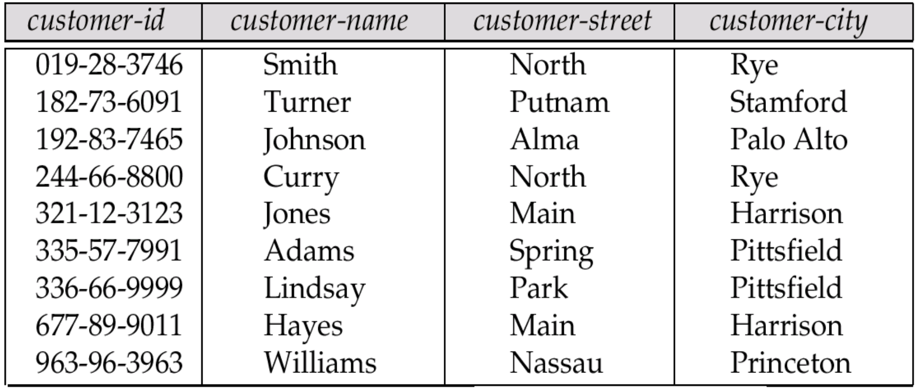
关系模式

Reduction to Relational Schemas

- **Reduction of an E-R diagram to tables**
  - In general, for each entity set and relationship set, there is a unique table
  - Each table has a number of attributes
  - Converting an E-R diagram to a table format is the basis for deriving a relational database design from an E-R diagram

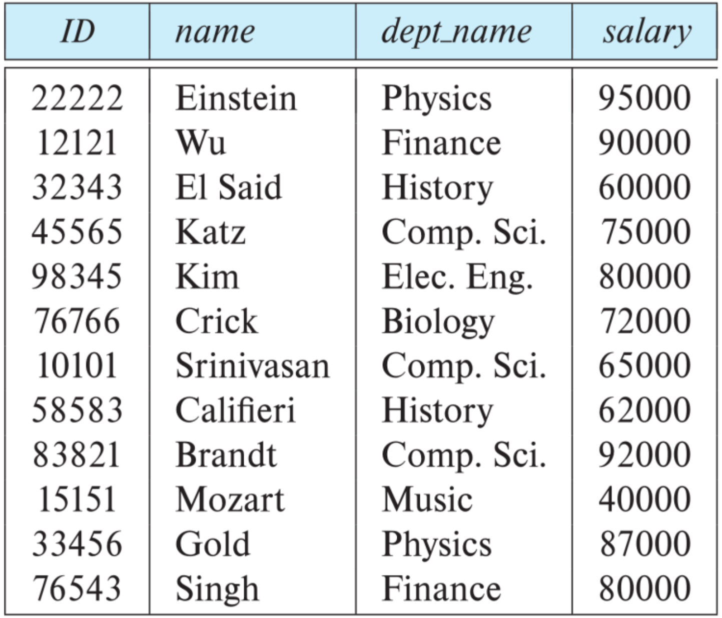
Representing Entity Sets as Tables

- A strong entity set is reduced to a table with the same attributes



customer-id	*customer-name*	*customer-street*	*customer-city*
019-28-3746	Smith	North	Rye
182-73-6091	Turner	Putnam	Stamford
192-83-7465	Johnson	Alma	Palo Alto
244-66-8800	Curry	North	Rye
321-12-3123	Jones	Main	Harrison
335-57-7991	Adams	Spring	Pittsfield
336-66-9999	Lindsay	Park	Pittsfield
677-89-9011	Hayes	Main	Harrison
963-96-3963	Williams	Nassau	Princeton

Customer



ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

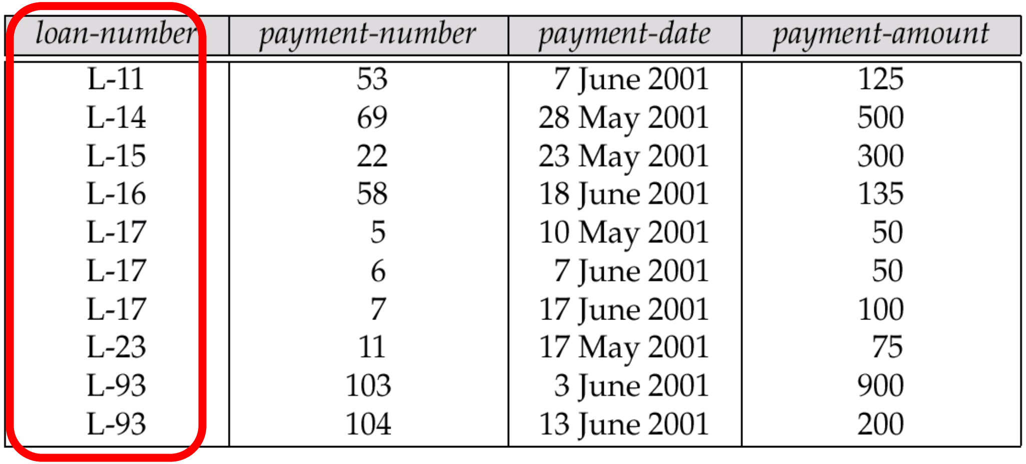
Instructor

Composite and Multi-valued Attributes

- **Composite attributes** are flattened out by creating a separate attribute for each component attribute
- A multi-valued attribute M of an entity E is represented by a separate table EM
  - Table EM has attributes corresponding to the primary key of E and an attribute corresponding to multivalued attribute M
  - Each value of the multivalued attribute maps to a separate row of the table EM

Representing Weak Entity Sets

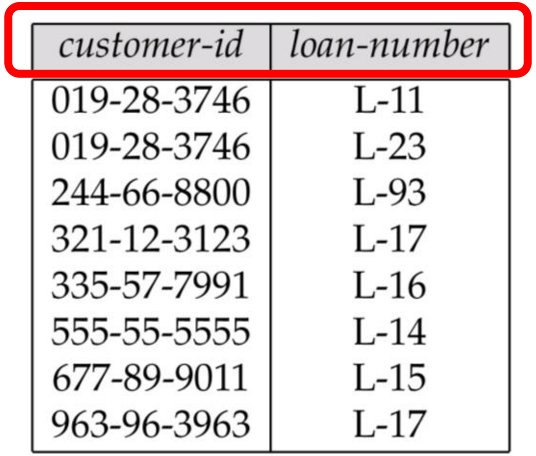
- A weak entity set becomes a table that includes a column for the primary key of the identifying strong entity set
- E.g., 还款记录



loan-number	*payment-number*	*payment-date*	*payment-amount*
L-11	53	7 June 2001	125
L-14	69	28 May 2001	500
L-15	22	23 May 2001	300
L-16	58	18 June 2001	135
L-17	5	10 May 2001	50
L-17	6	7 June 2001	50
L-17	7	17 June 2001	100
L-23	11	17 May 2001	75
L-93	103	3 June 2001	900
L-93	104	13 June 2001	200

Representing Relationship Sets as Tables

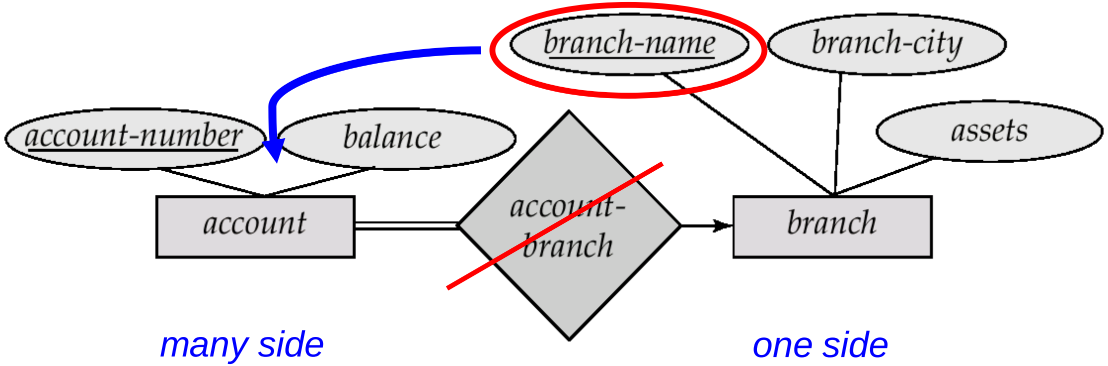
- **Many-to-many relationship set**
  - Represented as a table with columns for the primary keys of the two participating entity sets, and the attributes of the relationship set.
  - E.g., table for the relationship set borrower



customer-id	*loan-number*
019-28-3746	L-11
019-28-3746	L-23
244-66-8800	L-93
321-12-3123	L-17
335-57-7991	L-16
555-55-5555	L-14
677-89-9011	L-15
963-96-3963	L-17

Representing Relationship Sets as Tables

- **Many-to-one and one-to-many relationship sets**
  - Can be represented by adding an extra attribute to the many side, containing the primary key of the one side
  - E.g., instead of creating a table for relationship account-branch, add an attribute branch-name to the entity set account



Representing Relationship Sets as Tables

- **One-to-one relationship sets**
  - either side can be chosen to act as the “many” side

Representing Specialization as Tables

- **Method 1:**
  - Form a table for the higher level entity
  - Form a table for each lower level entity set, include primary key of higher level entity set and local attributes

table	**table attributes**
person	*name, street, city*
customer	*name, credit-rating*
employee	*name, salary*

  - **Drawback**: Querying information about entities, e.g., employee, requires accessing two tables

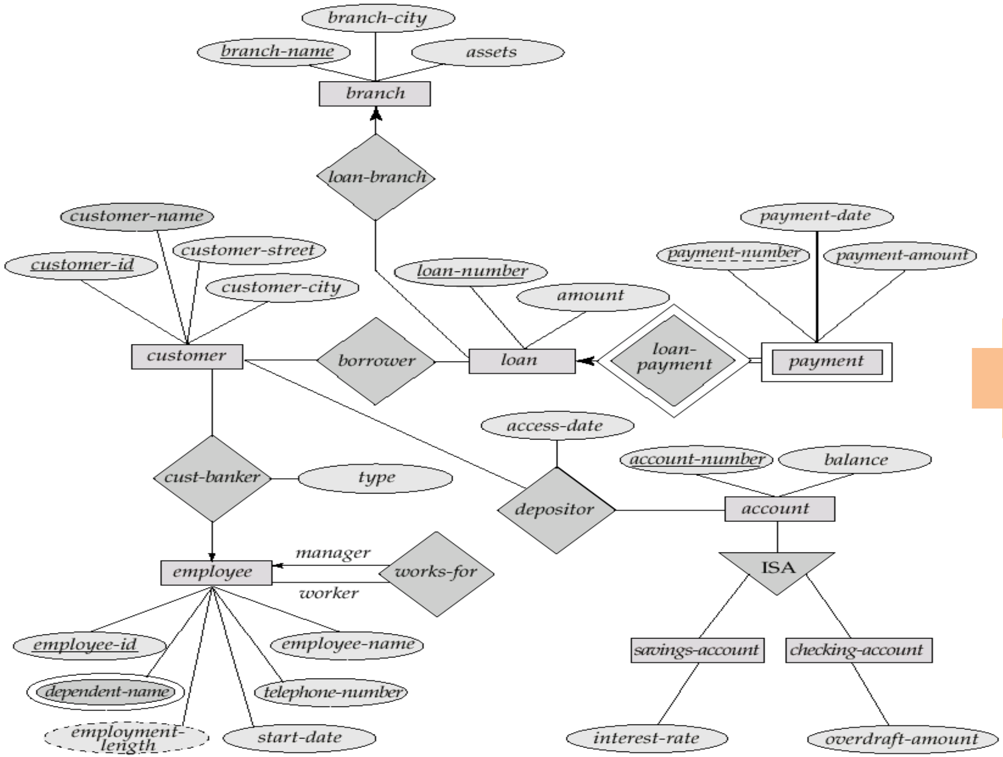
Representing Specialization as Tables (Cont.)

- **Method 2:**
  - Form a table for each entity set with all local and inherited attributes

table	**table attributes**
person	*name, street, city*
customer	*name, street, city, credit-rating*
employee	*name, street, city, salary*

  - **Drawback:** street and city are stored redundantly for customers and employees

E-R图和关系模式-Banking DB



E-R图

- *branch (branch_name, branch_city, assets)*
- *customer (customer_id, customer_name, customer_street, customer_city)*
- *loan (loan_number, amount)*
- *account (account_number, balance)*
- *employee (employee_id, employee_name, telephone_number, start_date)*

- *dependent_name (employee_id, dname)* (derived from a multivalued attribute)

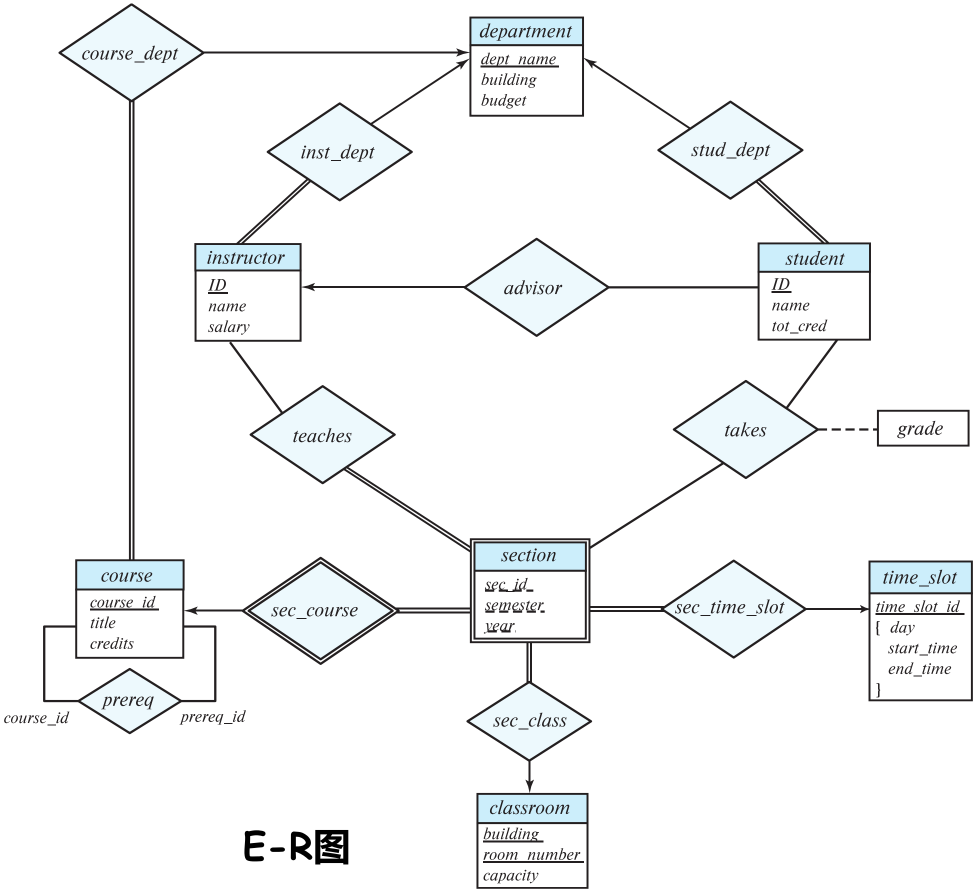
- *account_branch (account_number, branch_name)*
- *loan_branch (loan_number, branch_name)*
- *borrower (customer_id, loan_number)*
- *depositor (customer_id, account_number, access_date)*
- *cust_banker (customer_id, employee_id, type)*
- *works_for (worker_employee_id, manager_employee_id)*

- *Payment (loan_number, payment_number, payment_date, payment_amount)*

- *savings_account (account_number, interest_rate)*
- *checking_account (account_number, overdraft_amount)*

关系模式

E-R图和关系模式-University DB



E-R图

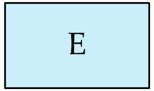
classroom(*building*, *room_number*, *capacity*)
department(*dept_name*, *building*, *budget*)
course(*course_id*, *title*, *credits*)
instructor(*ID*, *name*, *salary*)
student(*ID*, *name*, *tot_cred*)
teaches (*ID*, *course_id*, *sec_id*, *semester*, *year*)
takes (*ID*, *course_id*, *sec_id*, *semester*, *year*, *grade*)
prereq (*course_id*, *prereq_id*)
advisor (*s_ID*, *i_ID*)
sec_course (*course_id*, *sec_id*, *semester*, *year*)
sec_time_slot (*course_id*, *sec_id*, *semester*, *year*, *time_slot_id*)
sec_class (*course_id*, *sec_id*, *semester*, *year*, *building*, *room_number*)
inst_dept (*ID*, *dept_name*)
stud_dept (*ID*, *dept_name*)
course_dept (*course_id*, *dept_name*)

关系模式

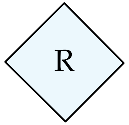
Stages of Database Design

- **S1: Requirement analysis**
  - Data storage requirement
  - Functional requirements analysis
    - Describe the operations that will be performed on the data
- **S2: Conceptual design (E-R Model)**
- **S3: Logical implementation**
  - Mapping from conceptual model to implementation model
  - E.g., relational model, OO model
- **S4: Physical implementation**
  - Specify physical features of the database, e.g., buffer size, index…

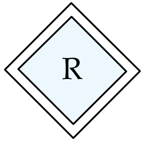
Symbols used in E-R Diagrams



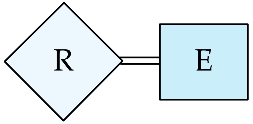
entity set



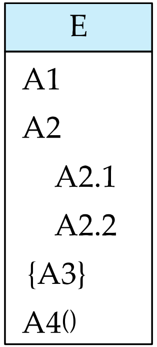
relationship set



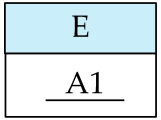
identifying
relationship set
for weak entity set



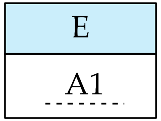
total participation
of entity set in
relationship



attributes:
simple (A1),
composite (A2) and
multivalued (A3)
derived (A4)

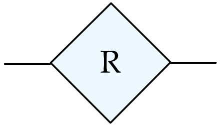


primary key

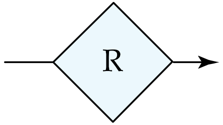


discriminating
attribute of
weak entity set

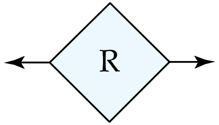
Symbols used in E-R Diagrams (Cont.)



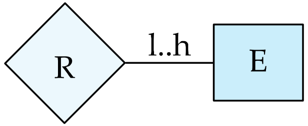
many-to-many relationship



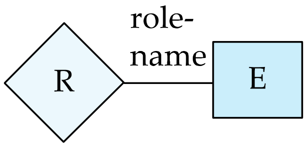
many-to-one relationship



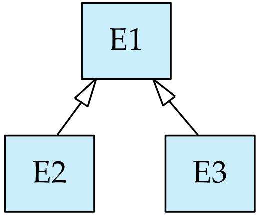
one-to-one relationship



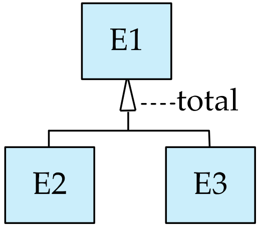
cardinality limits



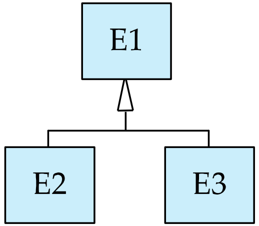
role indicator



ISA: generalization or specialization



total (disjoint) generalization



disjoint generalization

Design Tools

- **Freedgo Design**
  - https://www.freedgo.com/
- **Lucidchart**
  - https://www.lucidchart.com/pages/
- **Visual Paradigm**
  - https://www.visual-paradigm.com/cn/
- **Edrawmax**
  - https://www.edrawsoft.cn/

Summary of E-R Model

- Conceptual design follows requirements analysis
  - Yield a high-level description of data to be stored
- E-R model is popular for conceptual design
  - Constructs are expressive, close to the way people think about their applications
- Basic constructs: **entities**, **relationships**, and **attributes** (of entities and relationships)
- Additional constructs: weak entities, ISA hierarchies
- **Note**: There are many variants on E-R model

Summary of ER Model (Cont.)

- **Integrity constraints in E-R model**
  - Key constraints, participation constraints, and overlap/covering constraints for ISA hierarchies. Some foreign key constraints are also implicit in the definition of a relationship set
  - Some constraints (notably, functional dependencies) cannot be expressed in the E-R model

Summary of ER Model (Cont.)

- **E-R design is subjective**
  - There are often many ways to model a given scenario! Analyzing alternatives can be tricky, especially for a large enterprise. Common choices include:
    - Entity vs. attribute, entity vs. relationship, binary or n-ary relationship, whether or not to use ISA hierarchies

- **Ensuring good database design**
  - The generated relational schema should be analyzed and further refined
  - FD information and normalization techniques are useful (《数据库系统概念》第7章)