



Chapter 2: Intro to Relational Model

Database System Concepts, 7th Ed.

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Outline

- Structure of Relational Databases
- Database Schema
- Keys
- Schema Diagrams
- Relational Query Languages
- The Relational Algebra



Example of a *Instructor* Relation

属性
attributes
(or columns)

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

tuples 元组
(or rows)



Relation Schema and Instance

- A_1, A_2, \dots, A_n are *attributes*
- $R = (A_1, A_2, \dots, A_n)$ is a *relation schema*

关系模式

Example:

instructor = (ID, name, dept_name, salary)

关系实例 A relation instance r defined over schema R is denoted by $r(R)$.

- The current values a relation are specified by a table
- An element t of relation r is called a *tuple* and is represented by a *row* in a table



Attributes

- The set of allowed values for each attribute is called the **domain** of the attribute
域
- Attribute values are (normally) required to be **atomic**; that is, indivisible
原子性
- The special value ***null*** is a member of every domain. Indicated that the value is “unknown”
- The null value causes complications in the definition of many operations
复杂



Relations are Unordered

无序

- Order of tuples is irrelevant (tuples may be stored in an arbitrary order)
- Example: *instructor* relation with unordered tuples

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
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



Database Schema

- Database schema -- is the logical structure of the database.
- Database instance -- is a snapshot of the data in the database at a given instant in time.
- Example:
 - schema: *instructor* (*ID*, *name*, *dept_name*, *salary*)

- Instance:

快照

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
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



Keys

- Let $K \subseteq R$ 超码
- K is a **superkey** of R if values for K are sufficient to identify a unique tuple of each possible relation $r(R)$ 足够识别
 - Example: $\{ID\}$ and $\{ID, name\}$ are both superkeys of *instructor*.

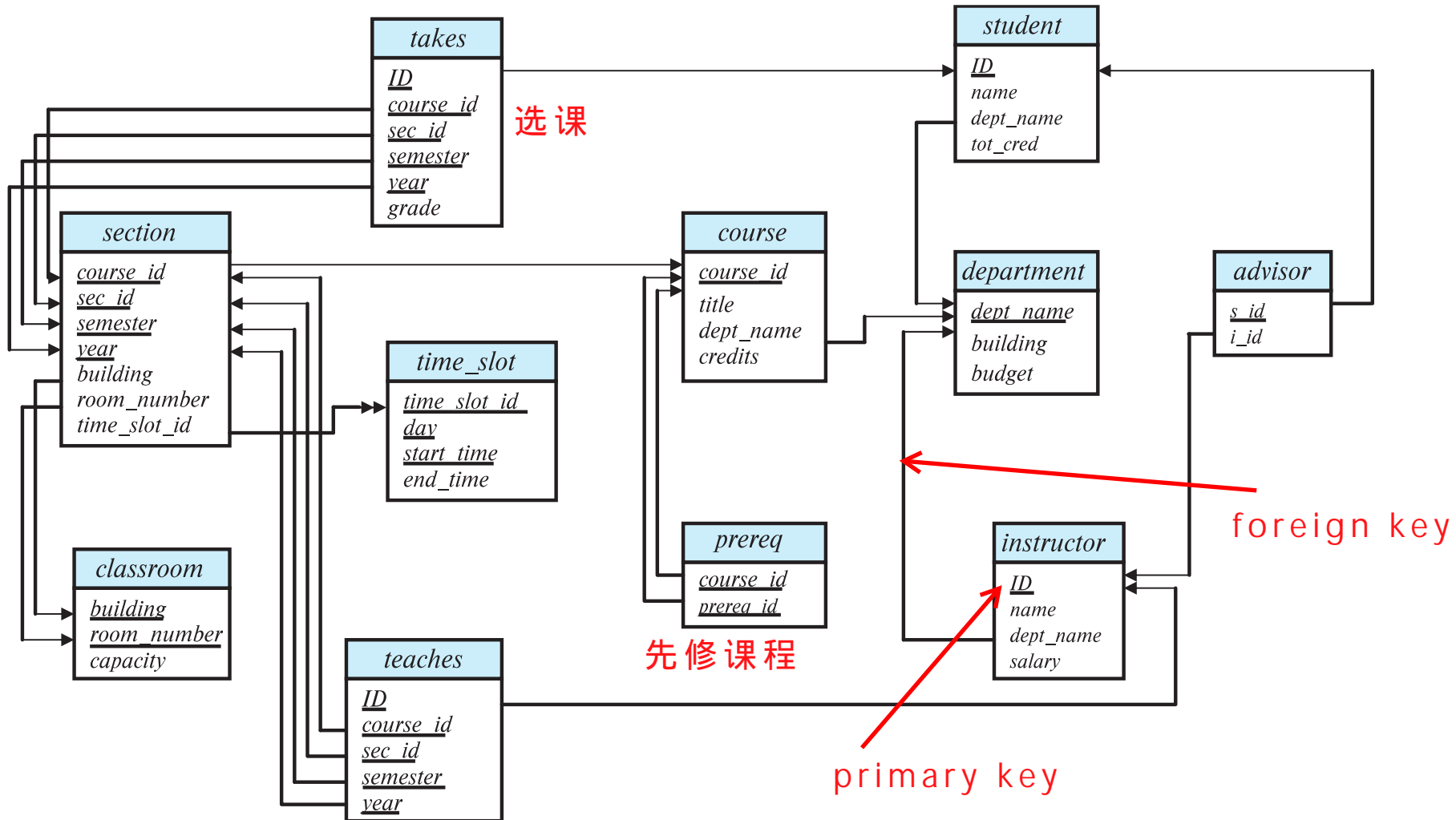
- 候选码
- Superkey K is a **candidate key** if K is minimal 比元素个数
 - Example: $\{ID\}$ is a candidate key for *Instructor*
 - One of the candidate keys is selected to be the **primary key**.
 - Which one? $\{ID\}$ 主键

- 外键
- **Foreign key** constraint: Value in one relation must appear in another 另一个relation
 - **Referencing** relation 参照关系
 - **Referenced** relation 被参照关系
 - Example: *dept_name* in *instructor* is a foreign key from *instructor* referencing *department*



Schema Diagram for University Database

ER图





Relational Query Languages

非过程化

- Procedural versus non-procedural, or declarative
- “Pure” languages:
 - Relational algebra 关系代数
 - Tuple relational calculus 计算
 - Domain relational calculus
- The above 3 pure languages are **equivalent** in computing power
- We will concentrate in this chapter on relational algebra
 - Not Turing-machine equivalent
 - Consists of 6 basic operations



Relational Algebra

- A procedural language consisting of a set of operations that take one or two relations as input and produce a new relation as their result.
- Six basic operators
 - select: σ
 - project: Π
 - union: \cup
 - set difference: $-$
 - Cartesian product: \times
 - rename: ρ



Select Operation

- The **select** operation selects tuples that satisfy a given predicate.
- Notation: $\sigma_p(r)$
- p is called the **selection predicate**
- Example: select those tuples of the *instructor* relation where the instructor is in the “Physics” department.
 - Query

谓词

$$\sigma_{dept_name="Physics"}(instructor)$$

- Result

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
22222	Einstein	Physics	95000
33456	Gold	Physics	87000



Select Operation (Cont.)

- We allow comparisons using

$=, \neq, >, \geq, <, \leq$

in the selection predicate.

- We can combine several predicates into a larger predicate by using the connectives:

\wedge (**and**), \vee (**or**), \neg (**not**)

- Example: Find the instructors in Physics with a salary greater \$90,000, we write:

$\sigma_{dept_name="Physics" \wedge salary > 90,000} (instructor)$

- The select predicate may include comparisons between two attributes.

- Example, find all departments whose name is the same as their building name:
- $\sigma_{dept_name=building} (department)$



Project Operation

投影运算

- A unary operation that returns its argument relation, with certain attributes left out.

- Notation:

$$\Pi_{A_1, A_2, A_3 \dots A_k} (r)$$

选择 k 列

where A_1, A_2, \dots, A_k are attribute names and r is a relation name.

- The result is defined as the relation of k columns obtained by erasing the columns that are not listed

擦除

- Duplicate rows removed from result, since relations are sets

重复元组移除



Project Operation Example

- Example: eliminate the *dept_name* attribute of *instructor*
- Query:

$\Pi_{ID, name, salary}(instructor)$

- Result:

<i>ID</i>	<i>name</i>	<i>salary</i>
10101	Srinivasan	65000
12121	Wu	90000
15151	Mozart	40000
22222	Einstein	95000
32343	El Said	60000
33456	Gold	87000
45565	Katz	75000
58583	Califieri	62000
76543	Singh	80000
76766	Crick	72000
83821	Brandt	92000
98345	Kim	80000



Composition of Relational Operations

复合

- The result of a relational-algebra operation is relation and therefore of relational-algebra operations can be composed together into a **relational-algebra expression**.
- Consider the query -- Find the names of all instructors in the Physics department.

$$\Pi_{name}(\sigma_{dept_name = "Physics"}(instructor))$$

- Instead of giving the name of a relation as the argument of the projection operation, we give an expression that evaluates to a relation.



Cartesian-Product Operation

笛卡尔积

- The Cartesian-product operation (denoted by \times) allows us to combine information from any two relations.
- Example: the Cartesian product of the relations *instructor* and *teaches* is written as:

instructor \times *teaches*

- We construct a tuple of the result out of each possible pair of tuples: one from the *instructor* relation and one from the *teaches* relation (see next slide) 匹配
- Since the instructor *ID* appears in both relations we distinguish between these attribute by attaching to the attribute the name of the relation from which the attribute originally came.
 - *instructor.ID*
 - *teaches.ID*

实际意义不大



The *instructor X teaches* table

<i>instructor.ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>	<i>teaches.ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
10101	Srinivasan	Comp. Sci.	65000	10101	CS-101	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	12121	FIN-201	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	15151	MU-199	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	22222	PHY-101	1	Fall	2017
...
...
12121	Wu	Finance	90000	10101	CS-101	1	Fall	2017
12121	Wu	Finance	90000	10101	CS-315	1	Spring	2018
12121	Wu	Finance	90000	10101	CS-347	1	Fall	2017
12121	Wu	Finance	90000	12121	FIN-201	1	Spring	2018
12121	Wu	Finance	90000	15151	MU-199	1	Spring	2018
12121	Wu	Finance	90000	22222	PHY-101	1	Fall	2017
...
...
15151	Mozart	Music	40000	10101	CS-101	1	Fall	2017
15151	Mozart	Music	40000	10101	CS-315	1	Spring	2018
15151	Mozart	Music	40000	10101	CS-347	1	Fall	2017
15151	Mozart	Music	40000	12121	FIN-201	1	Spring	2018
15151	Mozart	Music	40000	15151	MU-199	1	Spring	2018
15151	Mozart	Music	40000	22222	PHY-101	1	Fall	2017
...
...
22222	Einstein	Physics	95000	10101	CS-101	1	Fall	2017
22222	Einstein	Physics	95000	10101	CS-315	1	Spring	2018
22222	Einstein	Physics	95000	10101	CS-347	1	Fall	2017
22222	Einstein	Physics	95000	12121	FIN-201	1	Spring	2018
22222	Einstein	Physics	95000	15151	MU-199	1	Spring	2018
22222	Einstein	Physics	95000	22222	PHY-101	1	Fall	2017
...
...



Join Operation

- The Cartesian-Product

instructor X teaches

associates every tuple of instructor with every tuple of teaches.

- Most of the resulting rows have information about instructors who did NOT teach a particular course.
- To get only those tuples of “*instructor X teaches*” that pertain to instructors and the courses that they taught, we write:

$$\sigma_{instructor.id = teaches.id} (instructor \times teaches)$$

- We get only those tuples of “*instructor X teaches*” that pertain to instructors and the courses that they taught.
- The result of this expression, shown in the next slide



Join Operation (Cont.)

- The table corresponding to:

$$\sigma_{instructor.id = teaches.id}(instructor \times teaches)$$

<i>instructor.ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>	<i>teaches.ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
10101	Srinivasan	Comp. Sci.	65000	10101	CS-101	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2017
12121	Wu	Finance	90000	12121	FIN-201	1	Spring	2018
15151	Mozart	Music	40000	15151	MU-199	1	Spring	2018
22222	Einstein	Physics	95000	22222	PHY-101	1	Fall	2017
32343	El Said	History	60000	32343	HIS-351	1	Spring	2018
45565	Katz	Comp. Sci.	75000	45565	CS-101	1	Spring	2018
45565	Katz	Comp. Sci.	75000	45565	CS-319	1	Spring	2018
76766	Crick	Biology	72000	76766	BIO-101	1	Summer	2017
76766	Crick	Biology	72000	76766	BIO-301	1	Summer	2018
83821	Brandt	Comp. Sci.	92000	83821	CS-190	1	Spring	2017
83821	Brandt	Comp. Sci.	92000	83821	CS-190	2	Spring	2017
83821	Brandt	Comp. Sci.	92000	83821	CS-319	2	Spring	2018
98345	Kim	Elec. Eng.	80000	98345	EE-181	1	Spring	2017



Join Operation (Cont.)

- The **join** operation allows us to combine a select operation and a Cartesian-Product operation into a single operation.
- Consider relations $r(R)$ and $s(S)$
- Let “theta” be a predicate on attributes in the schema $R \cup S$. The join operation $r \bowtie_{\theta} s$ is defined as follows:

$$r \bowtie_{\theta} s = \sigma_{\theta} (r \times s)$$

- Thus

$$\sigma_{instructor.id = teaches.id} (instructor \times teaches)$$

- Can equivalently be written as

$$instructor \bowtie_{instructor.id = teaches.id} teaches.$$



Union Operation

并

- The union operation allows us to combine two relations
- Notation: $r \cup s$
- For $r \cup s$ to be valid. 参数相同
 1. r, s must have the **same arity** (same number of attributes)
 2. The attribute domains must be **compatible** (example: 2nd 域值兼容 column of r deals with the same type of values as does the 2nd column of s)
- Example: to find all courses taught in the Fall 2017 semester, or in the Spring 2018 semester, or in both

$\Pi_{course_id} (\sigma_{semester="Fall" \wedge year=2017} (section)) \cup$

$\Pi_{course_id} (\sigma_{semester="Spring" \wedge year=2018} (section))$



Union Operation (Cont.)

- Result of:

$$\Pi_{course_id} (\sigma_{semester="Fall" \wedge year=2017}(section)) \cup \\ \Pi_{course_id} (\sigma_{semester="Spring" \wedge year=2018}(section))$$

<i>course_id</i>
CS-101
CS-315
CS-319
CS-347
FIN-201
HIS-351
MU-199
PHY-101



Set-Intersection Operation

集合交

- The set-intersection operation allows us to find tuples that are in both the input relations.
- Notation: $r \cap s$
- Assume:
 - r, s have the *same arity*
 - attributes of r and s are compatible
- Example: Find the set of all courses taught in both the Fall 2017 and the Spring 2018 semesters.

$$\Pi_{course_id} (\sigma_{semester="Fall" \wedge year=2017}(section)) \cap \Pi_{course_id} (\sigma_{semester="Spring" \wedge year=2018}(section))$$

- Result

<i>course_id</i>
CS-101



Set Difference Operation

- The set-difference operation allows us to find tuples that are in one relation but are not in another.
- Notation $r - s$
- Set differences must be taken between **compatible** relations.
 - r and s must have the **same** arity
 - attribute domains of r and s must be compatible
- Example: to find all courses taught in the Fall 2017 semester, but not in the Spring 2018 semester

$\Pi_{course_id} (\sigma_{semester="Fall" \wedge year=2017}(section)) -$ 做差

$\Pi_{course_id} (\sigma_{semester="Spring" \wedge year=2018}(section))$

<i>course_id</i>
CS-347
PHY-101



The Assignment Operation

赋值

- It is convenient at times to write a relational-algebra expression by assigning parts of it to temporary relation variables.
- The assignment operation is denoted by \leftarrow and works like assignment in a programming language.
- Example: Find all instructor in the “Physics” and Music department.

$Physics \leftarrow \sigma_{dept_name=“Physics”}(instructor)$

$Music \leftarrow \sigma_{dept_name=“Music”}(instructor)$

$Physics \cup Music$

- With the assignment operation, a query can be written as a sequential program consisting of a series of assignments followed by an expression whose value is displayed as the result of the query.

也可以不用赋值直接交



The Rename Operation

更名

- The results of relational-algebra expressions do not have a name that we can use to refer to them. The rename operator, ρ , is provided for that purpose
- The expression:

$$\rho_x(E)$$

returns the result of expression E under the name x

- Another form of the rename operation:

$$\rho_{x(A1, A2, \dots, An)}(E)$$

取某几列



Equivalent Queries

等价查询

- There is more than one way to write a query in relational algebra.
- Example: Find information about courses taught by instructors in the Physics department with salary greater than 90,000

- Query 1

$$\sigma_{dept_name = \text{"Physics"} \wedge salary > 90,000} (instructor)$$

- Query 2

$$\sigma_{dept_name = \text{"Physics"}} (\sigma_{salary > 90,000} (instructor))$$

- The two queries are not identical; they are, however, equivalent -- they give the same result on any database.



Equivalent Queries

- There is more than one way to write a query in relational algebra.
- Example: Find information about courses taught by instructors in the Physics department
- Query 1

$\sigma_{dept_name="Physics"}(instructor \bowtie_{instructor.ID = teaches.ID} teaches)$

- Query 2

$(\sigma_{dept_name="Physics"}(instructor)) \bowtie_{instructor.ID = teaches.ID} teaches$

- The two queries are not identical; they are, however, equivalent -- they give the same result on any database.



End of Chapter 2