Database Management Systems (CSE-251)

Presented by

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Chapter 2: Intro to Relational Model

Database System Concepts, 7th Ed.

Table

- In relational model, ***relation*** is used to refer to the ***table***.
- A ***tuple*** is a sequence of values. It is used to refer to a row.
- A row in a table represents a ***relationship*** among a set of values. A relationship between n values is represented by an ***n-tuple*** of values.
- ***Attribute*** is used to refer to the column of a ***table***.

Relation Schema and Instance

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

  Example:

  instructor = (*ID*, *name*, *dept_name*, *salary*)
- 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

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: $\prod$
  - union: $\cup$, intersection: $\cap$
  - set difference: –
  - Cartesian product: x
  - rename: ρ
- Two basic types –
  - Unary – select, project, rename
  - Binary – union, cartesian product, set difference

Instance of *instructor* Relation

ID	*name*	*dept_name*	*salary*
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

Figure 2.1 The *instructor* relation.

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

$$\sigma_{dept\_name=\text{“Physics”}}(instructor)$$

- Result

ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
33456	Gold	Physics	87000

Instance of *department* Relation

dept_name	*building*	*budget*
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

Figure 2.5 The *department* relation.

Select Operation (Cont.)

- We allow comparisons using

  =, ≠, >, ≥. <. ≤

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

  ∧ (**and**), ∨ (**or**), ¬ (**not**)
- Example: **Find the instructors in Physics with a salary greater $90,000**, we write:

$$\sigma_{\textit{dept\_name}=\text{“Physics”} \wedge \textit{salary} > 90{,}000}(\textit{instructor})$$

- The select predicate may include comparisons between two attributes.
  - Example, **find all departments whose name is the same as their building name**:

$$\sigma_{\textit{dept\_name}=\textit{building}}(\textit{department})$$

Project Operation

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

$$\prod_{A1,A2,A3\ \ldots.Ak} (r)$$

  where A_1, A_2, …, 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
- Duplicate rows removed from result, since relations are sets

Project Operation Example

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

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

- Result:

ID	*name*	*salary*
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

- 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.**

$$\prod_{name}(\sigma_{dept\_name = \text{“Physics”}}(instructor))$$

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

Instance of *section* Relation

course_id	*sec_id*	*semester*	*year*	*building*	*room_number*	*time_slot_id*
BIO-101	1	Summer	2017	Painter	514	B
BIO-301	1	Summer	2018	Painter	514	A
CS-101	1	Fall	2017	Packard	101	H
CS-101	1	Spring	2018	Packard	101	F
CS-190	1	Spring	2017	Taylor	3128	E
CS-190	2	Spring	2017	Taylor	3128	A
CS-315	1	Spring	2018	Watson	120	D
CS-319	1	Spring	2018	Watson	100	B
CS-319	2	Spring	2018	Taylor	3128	C
CS-347	1	Fall	2017	Taylor	3128	A
EE-181	1	Spring	2017	Taylor	3128	C
FIN-201	1	Spring	2018	Packard	101	B
HIS-351	1	Spring	2018	Painter	514	C
MU-199	1	Spring	2018	Packard	101	D
PHY-101	1	Fall	2017	Watson	100	A

Figure 2.6 The *section* relation.

Union Operation

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

$$\Pi_{course\_id}\,(\sigma_{semester=\text{“Fall”}\ \wedge\ year=2017}(section))\ \cup$$
$$\Pi_{course\_id}\,(\sigma_{semester=\text{“Spring”}\ \wedge\ year=2018}(section))$$

Union Operation (Cont.)

- Result of:

$$\Pi_{course\_id}\,(\sigma_{\;semester=\text{“Fall”}\;\wedge\;year=2017}\,(section))\;\cup$$
$$\Pi_{course\_id}\,(\sigma_{\;semester=\text{“Spring”}\;\wedge\;year=2018}\,(section))$$

course_id
CS-101
CS-315
CS-319
CS-347
FIN-201
HIS-351
MU-199
PHY-101

Set-Intersection Operation

- 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.**

$$\Pi_{course\_id} (\sigma_{semester=\text{“Fall”} \land year=2017} (section)) \cap$$
$$\Pi_{course\_id} (\sigma_{semester=\text{“Spring”} \land year=2018} (section))$$

  - Result

course_id
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: **find all courses taught in the Fall 2017 semester, but not in the Spring 2018 semester**

$$\Pi_{course\_id} (\sigma_{semester=\text{“Fall”} \ \land\ year=2017} (section)) \ - \ \Pi_{course\_id} (\sigma_{semester=\text{“Spring”} \ \land\ year=2018} (section))$$

course_id
CS-347
PHY-101

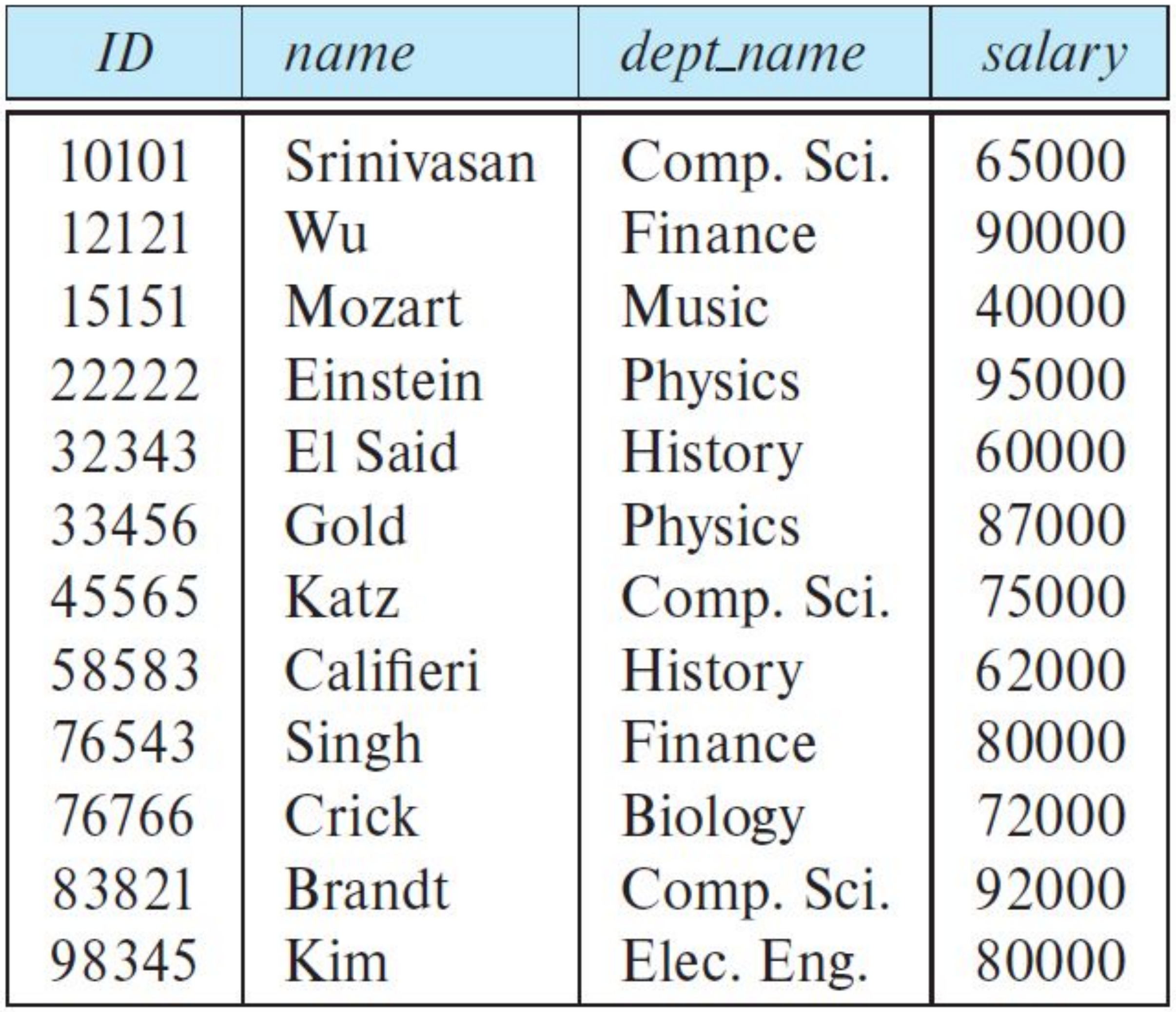
The Assignment Operation

- 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.**

$$Physics \leftarrow \sigma_{dept\_name=\text{"Physics"}}(instructor)$$
$$Music \leftarrow \sigma_{dept\_name=\text{"Music"}}(instructor)$$
$$Physics \cup Music$$

- 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.

Instance of *instructor* Relation



ID	*name*	*dept_name*	*salary*
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

Figure 2.1 The *instructor* relation.

Instance of *teaches* Relation

ID	*course_id*	*sec_id*	*semester*	*year*
10101	CS-101	1	Fall	2017
10101	CS-315	1	Spring	2018
10101	CS-347	1	Fall	2017
12121	FIN-201	1	Spring	2018
15151	MU-199	1	Spring	2018
22222	PHY-101	1	Fall	2017
32343	HIS-351	1	Spring	2018
45565	CS-101	1	Spring	2018
45565	CS-319	1	Spring	2018
76766	BIO-101	1	Summer	2017
76766	BIO-301	1	Summer	2018
83821	CS-190	1	Spring	2017
83821	CS-190	2	Spring	2017
83821	CS-319	2	Spring	2018
98345	EE-181	1	Spring	2017

Figure 2.7 The *teaches* relation.

Cartesian-Product Operation

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

  instructor x 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)
- 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*
- If there are two relations $r_1(R_1)$ and $r_2(R_2)$, then $r_1 \times r_2$ is a relation $r(R)$, which contains all tuples *t* for which there is a tuple t_1 in r_1 and a tuple t_2 in r_2.

The *instructor* x *teaches* *table*

instructor.ID	*name*	*dept_name*	*salary*	*teaches.ID*	*course_id*	*sec_id*	*semester*	*year*
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:

  $\sigma_{\textit{instructor.id} = \textit{teaches.id}}$ (*instructor* x *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:

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

instructor.ID	*name*	*dept_name*	*salary*	*teaches.ID*	*course_id*	*sec_id*	*semester*	*year*
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 "union" S. The join operation r $\bowtie_\theta$ s is defined as follows:

$$r \bowtie_\theta s = \sigma_\theta\,(r \times s)$$

- Thus

$$\sigma_{instructor.id = \ teaches.id}\,(instructor \ \text{x} \ teaches\ )$$

- Can equivalently be written as

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

The Rename Operation

- 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:

  $$\rho_{x(A1,A2, .. An)} (E)$$
- Example: **Find the ID and name of those instructors who earn more than the instructor whose ID is 12121.**

  $$\Pi_{i.ID,\ i.name} ((\sigma_{i.salary > w.salary} (\rho_i(instructor) \times \sigma_{w.id=12121} (\rho_w(instructor)))))$$