

RDBMS and SQL

Madhavan Mukund

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A Relational Model of Data for Large Shared Data Banks

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Future users of large data banks must be protected from having to know how the data is organized in the machine (the internal representation). A prompting service which supplies such information is not a satisfactory solution. Activities of users at terminals and most application programs should remain unaffected when the internal representation of data is changed and even when some aspects of the external representation are changed. Changes in data representation will often be needed as a result of changes in query, update, and report traffic and natural growth in the types of stored information.

The relational model

- All information is in tables (relations)

<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

Instructor

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>
BIO-101	Intro. to Biology	Biology	4
BIO-301	Genetics	Biology	4
BIO-399	Computational Biology	Biology	3
CS-101	Intro. to Computer Science	Comp. Sci.	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3
CS-319	Image Processing	Comp. Sci.	3
CS-347	Database System Concepts	Comp. Sci.	3
EE-181	Intro. to Digital Systems	Elec. Eng.	3
FIN-201	Investment Banking	Finance	3
HIS-351	World History	History	3
MU-199	Music Video Production	Music	3
PHY-101	Physical Principles	Physics	4

Course

The relational model

- All information is in tables (relations)
- How do we represent interrelationships — teaching allocation, prerequisites, timetable conflicts ...

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

Teaches

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

Instructor

course_id	title	dept_name	credits
BIO-101	Intro. to Biology	Biology	4
BIO-301	Genetics	Biology	4
BIO-399	Computational Biology	Biology	3
CS-101	Intro. to Computer Science	Comp. Sci.	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3
CS-319	Image Processing	Comp. Sci.	3
CS-347	Database System Concepts	Comp. Sci.	3
EE-181	Intro. to Digital Systems	Elec. Eng.	3
FIN-201	Investment Banking	Finance	3
HIS-351	World History	History	3
MU-199	Music Video Production	Music	3
PHY-101	Physical Principles	Physics	4

Course

The relational model

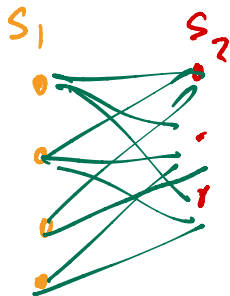
- All information is in tables (relations)
- How do we represent interrelationships — teaching allocation, prerequisites, timetable conflicts ...

<i>course_id</i>	<i>prereq_id</i>
BIO-301	BIO-101
BIO-399	BIO-101
CS-190	CS-101
CS-315	CS-101
CS-319	CS-101
CS-347	CS-101
EE-181	PHY-101

Prerequisites

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>
BIO-101	Intro. to Biology	Biology	4
BIO-301	Genetics	Biology	4
BIO-399	Computational Biology	Biology	3
CS-101	Intro. to Computer Science	Comp. Sci.	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3
CS-319	Image Processing	Comp. Sci.	3
CS-347	Database System Concepts	Comp. Sci.	3
EE-181	Intro. to Digital Systems	Elec. Eng.	3
FIN-201	Investment Banking	Finance	3
HIS-351	World History	History	3
MU-199	Music Video Production	Music	3
PHY-101	Physical Principles	Physics	4

Sets S_1, S_2



$$S_1 \times S_2 = \{(s_1, s_2) \mid s_1 \in S_1, s_2 \in S_2\}$$

Cartesian product

- All possible "connections" between S_1 & S_2

Relation $r \subseteq S_1 \times S_2$

$$S_1 = \mathbb{N}$$

$$S_2 = \mathbb{R}$$

$$S_1 \times S_2 = \{(n, r) \mid n \in \mathbb{N}, r \in \mathbb{R}\}$$

$$\text{sqrt} \subseteq S_1 \times S_2 = \{(n, \sqrt{n}) \mid n \in \mathbb{N}, \sqrt{n} \in \mathbb{R}\}$$

↑ $n \mapsto \sqrt{n}$ function

$$\{(n, -\sqrt{n}) \mid n \in \mathbb{N}, -\sqrt{n} \in \mathbb{R}\}$$

Relations

rc
↓
valid
dates

$S_1 \times S_2 \times S_3$

$S_1 = \{1, \dots, 31\}$

$S_2 = \{\text{Jan}, \dots, \text{Dec}\}$

$S_3 = \mathbb{N}$

$(16, \text{Jan}, 2026)$

$(31, \text{Feb}, 2026)$

Relations

- Tables have fixed structure — relation schema

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

Instructor

$S_1 \times S_2 \times S_3 \times S_4$

Instructor			
ID	name	dept_name	salary
Text	Text	Text	Number

Structure of table

Instance — specific values
respect format

Relations

- Tables have fixed structure — relation schema

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

Instructor

Instructor			
ID	name	dept_name	salary
Text	Text	Text	Number
Format?		Fixed set?	Range?

Sanity Check

Storage requirement

Data type

The relational model

- All information is stored as tables (relations)

<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
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58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

The relational model

- All information is stored as tables (relations)
- Mechanism for working with tables

<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

Instructor

The relational model

- All information is stored as tables (relations)
- Mechanism for working with tables
 - Describing table structure (schema)

<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

Instructor

The relational model

- All information is stored as tables (relations)
- Mechanism for working with tables
 - Describing table structure (schema)
 - Additions, deletions, modifications

<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

Instructor

The relational model

- All information is stored as tables (relations)
- Mechanism for working with tables
 - Describing table structure (schema)
 - Additions, deletions, modifications
 - Extracting useful information (querying)

<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
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76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

The relational model

- All information is stored as tables (relations)
- Mechanism for working with tables
 - Describing table structure (schema)
 - Additions, deletions, modifications
 - Extracting useful information (querying)
- Initially, focus on abstract query language

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
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76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — select and project

- List names of instructors from Physics department with salary above 90,000

Filter out rows

<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
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76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — select and project

- List names of instructors from Physics department with salary above 90,000
- List instructors from Physics department

Select all rows where
dept-name is "Physics"

σ_{deptname = "Physics"} (Instructor)

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
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98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — select and project

- List names of instructors from Physics department with salary above 90,000
- List instructors from Physics department

condition (Table name)

deptname = "Physics" (Instructor)

<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
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58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — select and project

- List names of instructors from Physics department with salary above 90,000
- List instructors from Physics department

What is the output of $\sigma_{\theta}(T)$?

<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
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83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — select and project

- List names of instructors from Physics department with salary above 90,000
- List instructors from Physics department **with salary above 90,000**

<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
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33456	Gold	Physics	87000
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76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

$\sigma_{\text{Salary} > 90000} \left(\sigma_{\text{dept} = \text{Physics}} (\text{Inst}) \right)$

x

Instructor

Relational algebra — select and project

- List instructors from Physics department with salary above 90,000
- List **names** of instructors from Physics department with salary above 90,000

Project $\sigma_{90000}(\sigma_{\text{Phy}}(\text{Inst}))$
on name
↓
 $\pi_{\text{name}}(\sigma_{\text{salary} > 90000}(\sigma_{\text{deptname} = \text{Physics}}(\text{Inst})))$

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
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Instructor

Relational algebra — select and project

- List instructors from Physics department with salary above 90,000
- List **names** of instructors from Physics department with salary above 90,000

Combine conditions

$\sigma_{\theta_1 \wedge \theta_2}$ **and** $\vee$ **or** $\wedge$ **and** $\cup$ **or** $\cap$ **and** $\neg$ **not**

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
10101	Srinivasan	Comp. Sci.	65000
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15151	Mozart	Music	40000
22222	Einstein	Physics	95000
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76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — select and project

- List instructors from Physics department with salary above 90,000
- List **names** of instructors from Physics department with salary above 90,000

$\pi_{\text{name}} \left(\sigma_{\text{deptname} = \text{Physics} \wedge \text{salary} > 90000} (\text{Instructor}) \right)$

<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
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76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — select and project

- List instructors from Physics department with salary above 90,000
- List **names** of instructors from Physics department with salary above 90,000

$$\begin{aligned} & \sigma_{\theta_2}(\sigma_{\theta_1}(\tau)) \\ & \sigma_{\theta_1}(\sigma_{\theta_2}(\tau)) \\ & \theta_1 \wedge \theta_2 = \theta_2 \wedge \theta_1 \end{aligned}$$

<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
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58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — select and project

- List instructors from Physics department with salary above 90,000
- List **names** of instructors from Physics department with salary above 90,000

$\pi_{\sigma(T)}$

$\sigma(\pi(T)) ?$

$\pi_{name}(T)$

<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

Instructor

Relational algebra — join

- List instructors who offer courses

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

Instructor

Combine tables

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

Teaches

Relational algebra — join

■ Instructor × Teaches

→ Filter this product

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
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...

for each row I in Instructor

for each row T in Teaches

if $I_id == T_id$...

Relational algebra — join

■ $\sigma_{\text{Instructor.ID} = \text{teaches.ID}}(\text{Instructor} \times \text{Teaches})$

table → project on to first half (or second column)

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

Relational algebra — join

■ $\text{Instructor} \bowtie \text{Teaches}$ — cartesian project with select

"bowtie"

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

Match
values on
common
columns

"natural"
join

$\pi_{T_1 T_2}$

Relations

vs

Tables

Sets

↓ List of rows

$$r \subseteq S_1 \times S_2$$

Duplicate rows ?

No duplicates

Order is unimportant

Output of ∇ , π , $\bowtie$

are always sets

No duplicates !

Relational algebra — join

- Find all taxpayers from Chennai with annual income over Rs 1 cr

Voter

Name	District
------	----------

Income Tax

Name	Salary
------	--------

Voter

Voter.Name = IncomeTax.Name

District = Chennai

Salary > 1 cr

Income Tax

A challenge

- List instructors who teach more than one course

ID₁

"Self join"

Teaches $\bowtie$ Teaches

↓
ID matches ?

Teacher.ID

Teacher.ID ???

$\bowtie$
course_id is different

<i>ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
✓ 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

Teaches

Relational algebra — assignment, renaming

Let

$T_1 \leftarrow \text{Teaches}$

$T_2 \leftarrow \text{Teaches}$

Programming
approach

In $T_1 \bowtie_{T_1.ID = T_2.ID \wedge T_1.course_id \neq T_2.course_id} T_2$

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

Teaches

Relational algebra — assignment, renaming

Algebraic approach

Renaming operator

Rename T as T_1



$\rho_{T_1}(\text{Teaches})$

$T_1.ID = T_2.ID$

$\wedge$
 $T_1.courseid \neq T_2.courseid$

$\sigma_{T_2}(\text{Teaches})$

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

Teaches