

RDBMS and SQL

Madhavan Mukund

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A Relational Model of Data for Large Shared Data Banks

Universal
model

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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 ...

<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

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

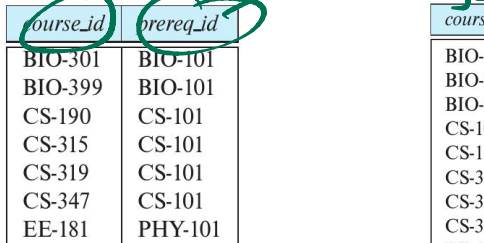
Instructor

<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 ...



<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

Course

Mathematically

Two sets S, T

$$S \times T = \{ (s, t) \mid s \in S, t \in T \}$$

$$r \subseteq S \times T$$

"Interesting pairs"

$$S = \mathbb{N}_0, T = \mathbb{N}_0$$

$$\mathbb{N} = \{0, 1, 2, 3, \dots\}$$

"divides" $x/y \Rightarrow y \bmod x = 0$
 $y \% x == 0$

$$\text{divides} \subseteq \mathbb{N}_0 \times \mathbb{N}_0 = \{ (x, y) \mid \begin{array}{l} x \in \mathbb{N}_0, y \in \mathbb{N}_0, \\ y \bmod x = 0 \end{array} \}$$

$r \subseteq \mathbb{N}_0 \times \mathbb{N}_0 \times \mathbb{N}_0$?

$$\text{pyth} = \{ (x, y, z) \mid \begin{array}{l} x, y, z \in \mathbb{N}_0, \\ x^2 + y^2 = z^2, \\ x, y, z > 0 \end{array} \}$$

Unary relation $\equiv$ Subject = Property / Predicate

$$r \subseteq \mathbb{N}_0$$

$$\text{even} = \{x \mid x \in \mathbb{N}_0, x \bmod 2 = 0\}$$

Relations

- Tables have fixed structure — relation

schema

template

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

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
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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

Instructor			
ID	name	dept_name	salary
Text	Text	Text	Number

Relations

- Tables have fixed structure — **relation schema**

<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

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

Relations vs Tables

↓
Set

x	y
2	4
3	6
1	1

↓
Order (sequence)
Duplicates are allowed

x	y
3	6
1	1
2	4
3	6

Factors = $\{ (2,4), (3,6), (1,1), (5,25), \dots \}$
↓
 (x,y) s.t.
 $x|y$

= $\{ (3,6), (2,4), (1,1), \dots \}$

$S =$ Member of a family

$\text{Parent} \subseteq S \times S$

The relational model

- All information is stored as tables (relations)

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83821	Brandt	Comp. Sci.	92000
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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
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32343	El Said	History	60000
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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)

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
10101	Srinivasan	Comp. Sci.	65000
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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

<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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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
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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>
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76766	Crick	Biology	72000
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98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — select and project

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

"Information need"

Select rows that satisfy a constraint

σ condition (relation)

σ dept_name = Physics (Instructor)

$\wedge$ (and) salary > 90000

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

Relational algebra — select and project

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

$\pi_{name} (Instructor)$

$\pi_{col1, col2, \dots, col_k} (relation)$

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

Relational algebra — select and project

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

- List names of instructors

- (List names) ^{π} of instructors from Physics department with salary above 90,000) ^{σ}

First select, then project

$\pi_{name} \left(\sigma_{\substack{dept_name = \text{Physics (Instr)} \\ salary > 90000}} \right)$

<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
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

Relational algebra — select and project

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

$\sigma_{dept_name = 'Physics'} (\pi_{name} (r))$

<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

Relational algebra — select and project

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

Handwritten annotations for the third query:

$\sigma_{\text{salary} > 90000}$ (green)

$\sigma_{\text{dept_name} = \text{Physics}}$ (red)

$\pi_{(\text{instr})}$ (green)

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

Relational algebra — select and project

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

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

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

Relational algebra — select and project

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

Select + Project

<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

Relational algebra — join

- List details of ~~courses offered by instructors~~

Instructors who offer courses

<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>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

for every row in Teaches

extract ID

for every row in Instructor

if this ID matches teaches ID $\rightarrow$ output

Relational algebra — join

■ Instructor × 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	✓
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	
...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	

Relational algebra — join

$\pi_{\text{col}_1, \dots, \text{col}_n} \sigma_{\text{Instructor.ID} = \text{teaches.ID}} (\text{Instructor} \times \text{Teaches})$

Cross Product + Select

<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

Relational algebra — join

- Instructor $\bowtie$ Instructor.ID = teaches.ID 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

$r_1 \bowtie_{\theta} r_2$

↑
cond

$\sigma_{\theta}(r_1 \times r_2)$

Relational algebra — join

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

Voter ID

Name	Dist

Tax

Name	Income

