RDBMS and SQL

Madhavan Mukund

https://www.cmi.ac.in/~madhavan

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Joins in SQL

- Join — cartesian product combined with selection

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- Join — cartesian product combined with selection
- Three specific types of join
  - Natural join
  - Outer join
  - Inner join

Natural join in SQL

- Match tuples with the same values for *all* common attributes
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```
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  from students, takes
    where student.ID = takes.ID;
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- Same query in SQL with natural join

```
select name, course_id
  from student natural join takes;
```

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select name, course_id
  from students, takes
    where student.ID = takes.ID;
```

- Same query in SQL with natural join

```
select name, course_id
  from student natural join takes;
```

- Can join multiple relations at a time

```
select A1, A2, ..., Am
 from r1 natural join r2
         natural join ...
         natural join rn
   where P ;
```

Student Relation

ID	*name*	*dept_name*	*tot_cred*
00128	Zhang	Comp. Sci.	102
12345	Shankar	Comp. Sci.	32
19991	Brandt	History	80
23121	Chavez	Finance	110
44553	Peltier	Physics	56
45678	Levy	Physics	46
54321	Williams	Comp. Sci.	54
55739	Sanchez	Music	38
70557	Snow	Physics	0
76543	Brown	Comp. Sci.	58
76653	Aoi	Elec. Eng.	60
98765	Bourikas	Elec. Eng.	98
98988	Tanaka	Biology	120

Takes Relation

ID	*course_id*	*sec_id*	*semester*	*year*	*grade*
00128	CS-101	1	Fall	2017	A
00128	CS-347	1	Fall	2017	A-
12345	CS-101	1	Fall	2017	C
12345	CS-190	2	Spring	2017	A
12345	CS-315	1	Spring	2018	A
12345	CS-347	1	Fall	2017	A
19991	HIS-351	1	Spring	2018	B
23121	FIN-201	1	Spring	2018	C+
44553	PHY-101	1	Fall	2017	B-
45678	CS-101	1	Fall	2017	F
45678	CS-101	1	Spring	2018	B+
45678	CS-319	1	Spring	2018	B
54321	CS-101	1	Fall	2017	A-
54321	CS-190	2	Spring	2017	B+
55739	MU-199	1	Spring	2018	A-
76543	CS-101	1	Fall	2017	A
76543	CS-319	2	Spring	2018	A
76653	EE-181	1	Spring	2017	C
98765	CS-101	1	Fall	2017	C-
98765	CS-315	1	Spring	2018	B
98988	BIO-101	1	Summer	2017	A
98988	BIO-301	1	Summer	2018	*null*

student natural join *takes*

only one copy of ID

ID	*name*	*dept_name*	*tot_cred*	*course_id*	*sec_id*	*semester*	*year*	*grade*
00128	Zhang	Comp. Sci.	102	CS-101	1	Fall	2017	A
00128	Zhang	Comp. Sci.	102	CS-347	1	Fall	2017	A-
12345	Shankar	Comp. Sci.	32	CS-101	1	Fall	2017	C
12345	Shankar	Comp. Sci.	32	CS-190	2	Spring	2017	A
12345	Shankar	Comp. Sci.	32	CS-315	1	Spring	2018	A
12345	Shankar	Comp. Sci.	32	CS-347	1	Fall	2017	A
19991	Brandt	History	80	HIS-351	1	Spring	2018	B
23121	Chavez	Finance	110	FIN-201	1	Spring	2018	C+
44553	Peltier	Physics	56	PHY-101	1	Fall	2017	B-
45678	Levy	Physics	46	CS-101	1	Fall	2017	F
45678	Levy	Physics	46	CS-101	1	Spring	2018	B+
45678	Levy	Physics	46	CS-319	1	Spring	2018	B
54321	Williams	Comp. Sci.	54	CS-101	1	Fall	2017	A-
54321	Williams	Comp. Sci.	54	CS-190	2	Spring	2017	B+
55739	Sanchez	Music	38	MU-199	1	Spring	2018	A-
76543	Brown	Comp. Sci.	58	CS-101	1	Fall	2017	A
76543	Brown	Comp. Sci.	58	CS-319	2	Spring	2018	A
76653	Aoi	Elec. Eng.	60	EE-181	1	Spring	2017	C
98765	Bourikas	Elec. Eng.	98	CS-101	1	Fall	2017	C-
98765	Bourikas	Elec. Eng.	98	CS-315	1	Spring	2018	B
98988	Tanaka	Biology	120	BIO-101	1	Summer	2017	A
98988	Tanaka	Biology	120	BIO-301	1	Summer	2018	*null*

Dangerous in Natural Join

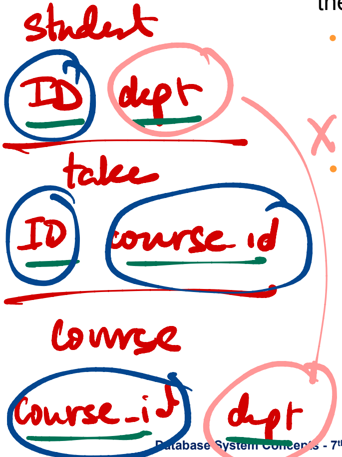
- Beware of unrelated attributes with same name which get equated incorrectly
- Example -- List the names of students instructors along with the titles of courses that they have taken
  - Correct version

    select *name*, *title*
    from *student* **natural join** *takes*, *course*
    where *takes*.*course_id* = *course*.*course_id*;

  - Incorrect version

    select *name*, *title*
    from *student* **natural join** *takes* **natural join** *course*;

    - This query omits all (student name, course title) pairs where the student takes a course in a department other than the student's own department.
    - The correct version (above), correctly outputs such pairs.



Women's T20 WC

List all players & runs scored

Teams

PlayerID	Name	Country

Runs Scored

PlayerID	Runs

Join Teams & RunsScored

```
select * from
    Teams natural join RunsScored
```

PlayerID	Name	Country	Runs

Misses out players who have not played

Outer join

If an entry is missing in the other table, add <u>null</u>

```
select * from
    RunsScored natural join Teams
```

Outer Join

- An extension of the join operation that avoids loss of information.
- Computes the join and then adds tuples form one relation that does not match tuples in the other relation to the result of the join.
- Uses *null* values.
- Three forms of outer join:
  - left outer join – extra values on left
  - right outer join – extra values on right
  - full outer join – extra values on both sides

Outer Join Examples

- Relation *course*

course_id	*title*	*dept_name*	*credits*
BIO-301	Genetics	Biology	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3

- Relation *prereq*

course_id	*prereq_id*
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

- Observe that

  course information is missing for CS-437

  prereq information is missing for CS-315

Left Outer Join

- *course* **natural left outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	*null*

- In relational algebra: *course* ⟕ *prereq*

Right Outer Join

- *course* **natural right outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-347	*null*	*null*	*null*	CS-101

- In relational algebra: *course* ⟖ *prereq*

Full Outer Join

- *course* **natural full outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	*null*
CS-347	*null*	*null*	*null*	CS-101

- In relational algebra: *course* ⟗ *prereq*

Joined Types and Conditions

- **Join operations** take two relations and return as a result another relation.
- These additional operations are typically used as subquery expressions in the **from** clause
- **Join condition** – defines which tuples in the two relations match, and what attributes are present in the result of the join.
- **Join type** – defines how tuples in each relation that do not match any tuple in the other relation (based on the join condition) are treated.

Join types
inner join
left outer join
right outer join
full outer join

Join conditions
natural
on <predicate>
using $(A_1, A_2, \ldots, A_n)$

Joined Relations – Examples

- *course* **natural right outer join** *prereq*

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-347	*null*	*null*	*null*	CS-101

- *course* **full outer join** *prereq* **using** (*course_id*)

course_id	*title*	*dept_name*	*credits*	*prereq_id*
BIO-301	Genetics	Biology	4	BIO-101
CS-190	Game Design	Comp. Sci.	4	CS-101
CS-315	Robotics	Comp. Sci.	3	*null*
CS-347	*null*	*null*	*null*	CS-101

Joined Relations – Examples

default

- *course* **inner join** *prereq* **on** *course.course_id = prereq.course_id*

course_id	*title*	*dept_name*	*credits*	*prereq_id*	*course_id*
BIO-301	Genetics	Biology	4	BIO-101	BIO-301
CS-190	Game Design	Comp. Sci.	4	CS-101	CS-190

- What is the difference between the above, and a natural join?
- *course* **left outer join** *prereq* **on** *course.course_id = prereq.course_id*

course_id	*title*	*dept_name*	*credits*	*prereq_id*	*course_id*
BIO-301	Genetics	Biology	4	BIO-101	BIO-301
CS-190	Game Design	Comp. Sci.	4	CS-101	CS-190
CS-315	Robotics	Comp. Sci.	3	*null*	*null*

Views in SQL

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- Hide sensitive information from some users — hide salary

```
select ID, name, dept_name
  from instructor
```

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select ID, name, dept_name
  from instructor
```

- Create convenient “intermediate tables”

```
select instructor.name, course.title
  from instructor,course natural join teaches
```

View Definition and Use

- A view of instructors without their salary

  create view *faculty* **as**
  select *ID*, *name*, *dept_name*
  from *instructor*

- Find all instructors in the Biology department

  select *name*
  from *faculty*
  where *dept_name* = 'Biology'

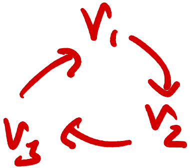
- Create a view of department salary totals

  create view *departments_total_salary(dept_name, total_salary)* **as**
  select *dept_name*, **sum** (*salary*)
  from *instructor*
  group by *dept_name*;

Views Defined Using Other Views

- One view may be used in the expression defining another view
- A view relation v_1 is said to *depend directly* on a view relation v_2 if v_2 is used in the expression defining v_1
- A view relation v_1 is said to *depend on* view relation v_2 if either v_1 depends directly to v_2 or there is a path of dependencies from v_1 to v_2
- A view relation v is said to be *recursive* if it depends on itself.

Avoid cyclic dependence



Views Defined Using Other Views

```sql
create view physics_fall_2017 as
    select course.course_id, sec_id, building, room_number
    from course, section
    where course.course_id = section.course_id
            and course.dept_name = 'Physics'
            and section.semester = 'Fall'
            and section.year = '2017';
```

```sql
create view physics_fall_2017_watson as
    select course_id, room_number
    from physics_fall_2017
    where building= 'Watson';
```

Materialized Views

- Certain database systems allow view relations to be physically stored.
  - Physical copy created when the view is defined.
  - Such views are called **Materialized view**:
- If relations used in the query are updated, the materialized view result becomes out of date
  - Need to **maintain** the view, by updating the view whenever the underlying relations are updated.

Update of a View

- Add a new tuple to *faculty* view which we defined earlier

  insert into *faculty*

  values ('30765', 'Green', 'Music');

- This insertion must be represented by the insertion into the *instructor* relation
  - Must have a value for salary.
- Two approaches
  - Reject the insert
  - Inset the tuple

    ('30765', 'Green', 'Music', null)

    into the *instructor* relation

Some Updates Cannot be Translated Uniquely

- **create view** *instructor_info* **as**
  select *ID*, *name*, *building*
  from *instructor*, *department*
  where *instructor*.*dept_name*= *department*.*dept_name*;
- **insert into** *instructor_info*
  values ('69987', 'White', 'Taylor');
- Issues
  - Which department, if multiple departments in Taylor?
  - What if no department is in Taylor?

And Some Not at All

- **create view** *history_instructors* **as**
  select *
  from *instructor*
  where *dept_name*= 'History';
- What happens if we insert

  ('25566', 'Brown', 'Biology', 100000)

  into *history_instructors?*

View Updates in SQL

- Most SQL implementations allow updates only on simple views
  - The **from** clause has only one database relation.
  - The **select** clause contains only attribute names of the relation, and does not have any expressions, aggregates, or **distinct** specification.
  - Any attribute not listed in the **select** clause can be set to null
  - The query does not have a **group** by or **having** clause.

Built-in Data Types in SQL

- **date:** Dates, containing a (4 digit) year, month and date
  - Example: **date** '2005-7-27'
- **time:** Time of day, in hours, minutes and seconds.
  - Example: **time** '09:00:30' **time** '09:00:30.75'
- **timestamp:** date plus time of day
  - Example: **timestamp** '2005-7-27 09:00:30.75'
- **interval:** period of time
  - Example: interval '1' day
  - Subtracting a date/time/timestamp value from another gives an interval value
  - Interval values can be added to date/time/timestamp values

Advanced SQL

- Many other features
  - Cascading updates to maintain referential integrity
  - Assertions and triggers
  - Transactions
  - . . .

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- Many other features
  - Cascading updates to maintain referential integrity
  - Assertions and triggers
  - Transactions
  - ...
- Can call SQL from other programming languages
  - Almost every language has library functions to invoke SQL
  - Transfer data between online forms and databases
  - ...

Security — SQL injection attacks

- User input can be malicious commands to corrupt database
- Always validate data entered in a form before passing on to SQL

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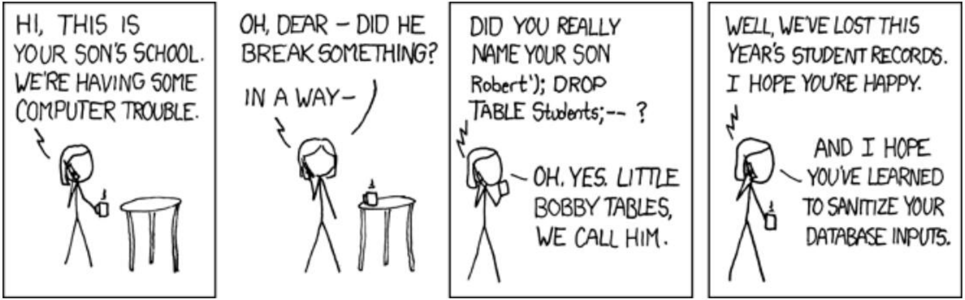

Relational database design

- Set of attributes that one needs to keep track of

Relational database design

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- Why not combine into a single table?

Relational database design

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

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

ID	*name*	*dept_name*	*salary*
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History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

- Combine these into a single table?

Relational database design

ID	*name*	*salary*	*dept_name*	*building*	*budget*
22222	Einstein	95000	Physics	Watson	70000
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Relational database design

- Redundant storage

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22222	Einstein	95000	Physics	Watson	70000
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98345	Kim	80000	Elec. Eng.	Taylor	85000
76766	Crick	72000	Biology	Watson	90000
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15151	Mozart	40000	Music	Packard	80000
33456	Gold	87000	Physics	Watson	70000
76543	Singh	80000	Finance	Painter	120000

Relational database design

- Redundant storage
- Maintaining consistency
  - Updates
  - Inserts and deletes

ID	*name*	*salary*	*dept_name*	*building*	*budget*
22222	Einstein	95000	Physics	Watson	70000
12121	Wu	90000	Finance	Painter	120000
32343	El Said	60000	History	Painter	50000
45565	Katz	75000	Comp. Sci.	Taylor	100000
98345	Kim	80000	Elec. Eng.	Taylor	85000
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10101	Srinivasan	65000	Comp. Sci.	Taylor	100000
58583	Califieri	62000	History	Painter	50000
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15151	Mozart	40000	Music	Packard	80000
33456	Gold	87000	Physics	Watson	70000
76543	Singh	80000	Finance	Painter	120000

Instructor, Department ← decompose — Starting Point

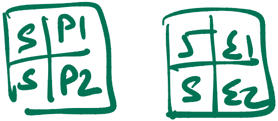
Decomposition and information

- (customer_name,regd_phone,regd_email)

Decomposition and information

- (customer_name,regd_phone,regd_email)
- Decompose as (customer_name,regd_phone) and (customer_name,regd_email)

not unique



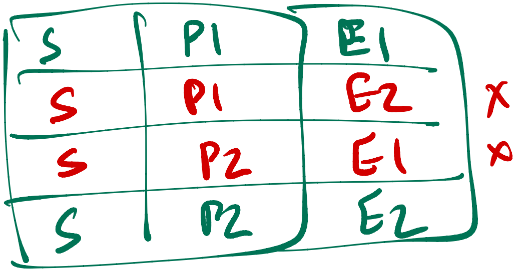
Srinivasan, Phone 1, Email 1
Srinivasan, Phone 2, Email 2

Decomposition and information

- `(customer_name,regd_phone,regd_email)`
- Decompose as `(customer_name,regd_phone)` and `(customer_name,regd_email)`
- Name is not unique — loss of information

Decomposition and information

- (customer_name,regd_phone,regd_email)
- Decompose as (customer_name,regd_phone) and (customer_name,regd_email)
- Name is not unique — loss of information
- Recombining decomposed relation should not add tuples



Decomposition and information

- (customer_name,regd_phone,regd_email)
- Decompose as (customer_name,regd_phone) and (customer_name,regd_email)
- Name is not unique — loss of information
- Recombining decomposed relation should not add tuples
- Lossless decomposition
  - Decompose R as R_1 and R_2
  - Want $R = R_1 \bowtie R_2$

If $R_1 \cap R_2$ is empty

$R_1 \bowtie R_2$ is $R_1 \times R_2$

Functional dependencies

- $A_1, A_2, \ldots, A_k \rightarrow B_1, B_2, \ldots B_m$
  - LHS atributes uniquely fix RHS attributes
  - Must hold for every instance — semantic property of attributes

ID	*name*	*salary*	*dept_name*	*building*	*budget*
22222	Einstein	95000	Physics	Watson	70000
12121	Wu	90000	Finance	Painter	120000
32343	El Said	60000	History	Painter	50000
45565	Katz	75000	Comp. Sci.	Taylor	100000
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Functional dependencies

- $A_1, A_2, \ldots, A_k \rightarrow B_1, B_2, \ldots B_m$
  - LHS atributes uniquely fix RHS attributes
  - Must hold for every instance — semantic property of attributes
- Need not correspond to superkeys
  - `dept_name` $\rightarrow$ `building`
  - `dept_name` $\rightarrow$ `budget`

ID	*name*	*salary*	*dept_name*	*building*	*budget*
22222	Einstein	95000	Physics	Watson	70000
12121	Wu	90000	Finance	Painter	120000
32343	El Said	60000	History	Painter	50000
45565	Katz	75000	Comp. Sci.	Taylor	100000
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Functional dependencies

- $A_1, A_2, \ldots, A_k \rightarrow B_1, B_2, \ldots B_m$
  - LHS atributes uniquely fix RHS attributes
  - Must hold for every instance — semantic property of attributes
- Need not correspond to superkeys
  - dept_name → building
  - dept_name → budget
- Use to identify sources of redundancy, guide decomposition

ID	*name*	*salary*	*dept_name*	*building*	*budget*
22222	Einstein	95000	Physics	Watson	70000
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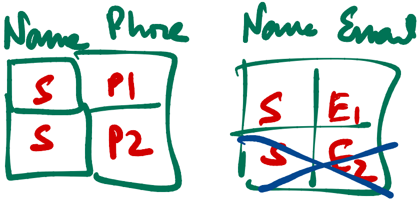
76766	Crick	72000	Biology	Watson	90000
10101	Srinivasan	65000	Comp. Sci.	Taylor	100000
58583	Califieri	62000	History	Painter	50000
83821	Brandt	92000	Comp. Sci.	Taylor	100000
15151	Mozart	40000	Music	Packard	80000
33456	Gold	87000	Physics	Watson	70000
76543	Singh	80000	Finance	Painter	120000

Lossless decomposition and functional dependencies

- Decompose R as R_1 and R_2

Lossless decomposition and functional dependencies

- Decompose R as R_1 and R_2
- Decomposition is lossless if at least one of the following functional dependencies hold
  - $R_1 \cap R_2 \rightarrow R_1$
  - $R_1 \cap R_2 \rightarrow R_2$



Use this to guide decomposition