Select all

- From the *classroom* relation in the figure, find the names of buildings in which every individual classroom has capacity less than 100 (without removing the duplicates).

building	*room_number*	*capacity*
Packard	101	500
Painter	514	10
Taylor	3128	70
Watson	100	30
Watson	120	50

Figure: *classroom* relation

- Query:

  select all *building*
  from *classroom*
  where *capacity* $<$ 100;

- Output:

building
Painter
Taylor
Watson
Watson

- Note that duplicate retention is the default and hence it is a common practice to skip *all* immediately after *select*.

Cartesian Product

- Find the list of all students of departments which have a budget $< \$0.1 million$

  select *name*, *budget*
  from *student*, *department*
  where *student.dept_name* = *department.dept_name* **and** *budget* < 100000;

- The above query first generates every possible student-department pair, which is the Cartesian product of student and department. Then, it filters all the rows with *student.dept_name* = *department.dept_name* **and** *budget* < 100000.
- The common attribute *dept_name* in the resulting table are renamed using the relation name - *student.dept_name* and *department.dept_name*)

name	*budget*
Brandt	50000.00
Peltier	70000.00
Levy	70000.00
Sanchez	80000.00
Snow	70000.00
Aoi	85000.00
Bourikas	85000.00
Tanaka	90000.00

Rename AS Operation

- The same query in the previous slide can be framed by renaming the tables as shown below.

  select *S.name* **as** *studentname*, *budget* **as** *deptbudget*
  from *student* **as** *S*, *department* **as** *D*
  where *S.dept_name* = *D.dept_name* **and** *budget* < 100000;

  D.budget/
  no budget col in students unlike department name

- The above query renames the relation *student* **as** *S* and the relation *department* **as** *D*
- It also displays the attribute *name* as StudentName and *budget* as DeptBudget.
- Note that the budget attribute does not have any prefix because it occurs only in the department relation.

studentname	*deptbudget*
Brandt	50000.00
Peltier	70000.00
Levy	70000.00
Sanchez	80000.00
Snow	70000.00
Aoi	85000.00
Bourikas	85000.00
Tanaka	90000.00

Where: AND and OR

- From the *instructor* and *department* relations in the figure, find out the names of all instructors whose department is Finance or whose department is in any of the following buildings: Watson, Taylor.

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

department

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

  - Query:

    select *name*
    from *instructor I*, *department D*
    where *D.dept_name* = *I.dept_name*
    and (*I.dept_name* = 'Finance'
    or *building* **in** ('Watson','Taylor'));

  - Output:

name
Srinivasan
Wu
Einstein
Gold
Katz
Singh
Crick
Brandt
Kim

Order By

- From the *student* relation in the figure, obtain the list of all students in alphabetic order of departments and within each department, in decreasing order of total credits.

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

Figure: *student* relation

- The list is first sorted in alphabetic order of dept name.
- Within each dept, it is sorted in decreasing order of total credits.

- Query:

  select *name*, *dept_name*, *tot_cred*
  from *student*
  order by *dept_name* **ASC**, *tot_cred* **DESC**;

- Output:

name	*dept_name*	*tot_cred*
Tanaka	Biology	120
Zhang	Comp. Sci.	102
Brown	Comp. Sci.	58
Williams	Comp. Sci.	54
Shankar	Comp. Sci.	32
Bourikas	Elec. Eng.	98
Aoi	Elec. Eng.	60
Chavez	Finance	110
Brandt	History	80
Sanchez	Music	38
Peltier	Physics	56
Levy	Physics	46
Snow	Physics	0

Set Operations: union

- For the same question in the previous slide, we can find the solution using **union** operator as follows.

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: *teaches* relation

- Query:

  select *course_id*
  from *teaches*
  where *semester*=‘*Fall*’
    and *year*=2018
  union
  select *course_id*
  from *teaches*
  where *semester*=‘*Spring*’
    and *year*=2018

- Output:

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

- Note that **union** removes all duplicates. If we use **union all** instead of **union**, we get the same set of tuples as in previous slide.

Aggregate functions: avg

- From the *classroom* relation given in the figure, find the names and the average capacity of each building whose average capacity is greater than 25.

building	*room_number*	*capacity*
Packard	101	500
Painter	514	10
Taylor	3128	70
Watson	100	30
Watson	120	50

Figure: *classroom* relation

  - Query:

    select *building*, **avg** (*capacity*)
    from *classroom*
    group by *building*
    having **avg** (*capacity*) > 25;

  - Output:

building	*avg*
Taylor	70.00
Packard	500.00
Watson	40.00

Nested Subqueries

- SQL provides a mechanism for the nesting of subqueries
- A **subquery** is a **select-from-where** expression that is nested within another query
- The nesting can be done in the following SQL query

  select $A_1, A_2, \ldots, A_n$
  from $r_1, r_2, \ldots, r_m$
  where P

  as follows:
  - A_i can be replaced by a subquery that generates a single value
  - r_i can be replaced by any valid subquery
  - P can be replaced with an expression of the form:

    B <operation> (subquery)

    where B is an attribute and <operation> to be defined later

Subqueries in the Where Clause

- Typical use of subqueries is to perform tests:
  - For set membership
  - For set comparisons
  - For set cardinality

Set Comparison – “some” Clause

- Find names of instructors with salary greater than that of some (at least one) instructor in the Biology department

  select distinct *T.name*
  from *instructor* **as** *T*, *instructor* **as** *S*
  where *T.salary* > *S.salary* **and** *S.dept name* = 'Biology';

- Same query using **some** clause

  select *name*
  from *instructor*
  where *salary* > **some** (**select** *salary*
  from *instructor*
  where *dept_name* = *'Biology'*);

Definition of "some" Clause

there exists a tuple that belongs to r

- F <comp> **some** $r \Leftrightarrow \exists t \in r$ such that (F <comp> t)
  where <comp> can be: $<, \leq, >, \geq, =, \neq$
- **some** represents existential quantification

$$(5 < \textbf{some} \begin{array}{|c|}\hline 0 \\ \hline 5 \\ \hline 6 \\ \hline\end{array}) = \text{true}$$

(read: 5 < some tuple in the relation)

$$(5 < \textbf{some} \begin{array}{|c|}\hline 0 \\ \hline 5 \\ \hline\end{array}) = \text{false}$$

$$(5 = \textbf{some} \begin{array}{|c|}\hline 0 \\ \hline 5 \\ \hline\end{array}) = \text{true}$$

$$(5 \neq \textbf{some} \begin{array}{|c|}\hline 0 \\ \hline 5 \\ \hline\end{array}) = \text{true (since } 0 \neq 5)$$

(= **some**) ≡ **in**
However, (≠ **some**) ≢ **not in**

Set Comparison – "all" Clause

- Find the names of all instructors whose salary is greater than the salary of all instructors in the Biology department

  select *name*
  from *instructor*
  where *salary* > **all** (**select** *salary*
  from *instructor*
  where *dept_name* = *'Biology'*);

Definition of "all" Clause

Module 12

Partha Pratim Das

Objectives & Outline

Nested Subqueries

Subqueries in the Where Clause

Subqueries in the From Clause

Subqueries in the Select Clause

Modifications of the Database

Module Summary

for all

- F <comp> **all** $r \Leftrightarrow \forall t \in r$ such that (F <comp> t)
  Where <comp> can be: $<, \leq, >, \geq, =, \neq$
- **all** represents universal quantification

$(5 < \textbf{all} \begin{array}{|c|}\hline 0 \\ \hline 5 \\ \hline 6 \\ \hline \end{array}) = \text{false}$

$(5 < \textbf{all} \begin{array}{|c|}\hline 6 \\ \hline 10 \\ \hline \end{array}) = \text{true}$

$(5 = \textbf{all} \begin{array}{|c|}\hline 4 \\ \hline 5 \\ \hline \end{array}) = \text{false}$

$(5 \neq \textbf{all} \begin{array}{|c|}\hline 4 \\ \hline 6 \\ \hline \end{array}) = \text{true (since } 5 \neq 4 \text{ and } 5 \neq 6)$

($\neq$ **all**) $\equiv$ **not in**
However, (= **all**) $\not\equiv$ **in**

Test for Empty Relations: "exists"

- The **exists** construct returns the value **true** if the argument subquery is nonempty
  - **exists** $r \Leftrightarrow r \neq \emptyset$
  - **not exists** $r \Leftrightarrow r = \emptyset$

Use of "exists" Clause

- Yet another way of specifying the query "Find all courses taught in both the Fall 2009 semester and in the Spring 2010 semester"

  select *course_id*
  from *section* **as** *S*
  where *semester* = 'Fall' and *year* = 2009 and
  exists (**select** *
  from *section* **as** *T*
  where *semester* = 'Spring' and *year* = 2010
  and *S.course_id* = *T.course_id*);

- **Correlation name** – variable *S* in the outer query
- **Correlated subquery** – the inner query

Use of "not exists" Clause

- Find all students who have taken all courses offered in the Biology department.

```
select distinct S.ID, S.name
from student as S
where not exists ( (select course_id
                    from course
                    where dept_name = 'Biology')
                    except
                    (select T.course_id
                          from takes as T
                          where S.ID = T.ID));
```

  - First nested query lists all courses offered in Biology
  - Second nested query lists all courses a particular student took
- Note: $X - Y = \emptyset \Leftrightarrow X \subseteq Y$
- Note: Cannot write this query using = **all** and its variants

Test for Absence of Duplicate Tuples: "unique"

- The **unique** construct tests whether a subquery has any duplicate tuples in its result
- The **unique** construct evaluates to "true" if a given subquery contains no duplicates
- Find all courses that were offered at most once in 2009

select *T.course_id*
from *course* **as** *T*
where **unique** (**select** *R.course_id*
  from *section* **as** *R*
  where *T.course_id* = *R.course_id*
  and *R.year* = 2009);

Subqueries in the From Clause

- SQL allows a subquery expression to be used in the **from** clause
- Find the average instructors' salaries of those departments where the average salary is greater than $42,000

  select *dept_name*, *avg_salary*
  from (**select** *dept_name*, **avg**(*salary*) **as** *avg_salary*
  from *instructor*
  group by *dept_name*)
  where *avg_salary* > 42000;

- Note that we do not need to use the **having** clause
- Another way to write above query

  select *dept_name*, *avg_salary*
  from (**select** *dept_name*, **avg** (salary)
  from *instructor*
  group by *dept_name*) **as** *dept_avg* (*dept_name*, *avg_salary*)
  where *avg_salary* > 42000;

With Clause

- The **with** clause provides a way of defining a temporary relation whose definition is available only to the query in which the **with** clause occurs
- Find all departments with the maximum budget

  with *max_budget(value)* **as**
      (**select** **max**(*budget*)
      from *department*)
  select *department.name*
  from *department, max_budget*
  where *department.budget=max_budget.value*;

Subqueries in the Select Clause

Scalar Subquery

- Scalar subquery is one which is used where a single value is expected
- List all departments along with the number of instructors in each department

  select *dept_name*,
  (**select count(*)**
  from *instructor*
  where *department.dept_name* = *instructor.dept_name*)
  as *num_instructors*
  from *department*;
- Runtime error if subquery returns more than one result tuple

Modification of the Database

- Deletion of tuples from a given relation
- Insertion of new tuples into a given relation
- Updating of values in some tuples in a given relation

Deletion

- Delete all instructors

  delete from *instructor*

- Delete all instructors from the Finance department

  delete from *instructor*
  where *dept_name*= 'Finance';

- Delete all tuples in the *instructor* relation for those instructors associated with a department located in the Watson building

  delete from *instructor*
  where *dept_name* **in** (**select** *dept_name*
  from *department*
  where *building* = 'Watson');

Deletion (2)

- Delete all instructors whose salary is less than the average salary of instructors

  delete from *instructor*
  where *salary* < (**select avg** (*salary*)
  from *instructor*);

- Problem: as we delete tuples from deposit, the average salary changes
- Solution used in SQL:
  a) First, compute **avg** (salary) and find all tuples to delete
  b) Next, delete all tuples found above (without recomputing **avg** or retesting the tuples)

Insertion

- Add a new tuple to course

  insert into *course*
  values ('CS-437', 'Database Systems', 'Comp. Sci.', 4);

- or equivalently:

  insert into *course (course_id, title, dept_name, credits)*
  values ('CS-437', 'Database Systems', 'Comp. Sci.', 4);

- Add a new tuple to student with *tot_creds* set to null

  insert into *student*
  values ('3003', 'Green', 'Finance', *null*);

Insertion (2)

- Add all instructors to the *student* relation with *tot_creds* set to 0

  insert into *student*
  select *ID*, *name*, *dept_name*, 0
  from *instructor*

- The **select from where** statement is evaluated fully before any of its results are inserted into the relation

- Otherwise queries like

  insert into *table1* **select * from** *table1*

  would cause problem

Updates

- Increase salaries of instructors whose salary is over \$100,000 by 3%, and all others by a 5%
  - Write two **update** statements:

    update *instructor*
        set *salary* $=$ *salary* $* 1.03$
        where *salary* > 100000;
    update *instructor*
        set *salary* $=$ *salary* $* 1.05$
        where *salary* $<= 100000$;

- The order is important
- Can be done better using the **case** statement (next slide)

Case Statement for Conditional Updates

- Same query as before but with **case statement**

  update *instructor*
  set *salary* = **case**
  when *salary* <= 100000
  then *salary* * 1.05
  else *salary* * 1.03
  end

Updates with Scalar Subqueries

- Recompute and update tot_creds value for all students

  update *student S*
  set *tot_creds* = (**select sum**(*credits*)
  from *takes, course*
  where *takes.course_id* = *course.course_id* **and**
  S.ID = *takes.ID* **and**
  takes.grade <> 'F' **and**
  takes.grade **is not null**);

- Sets *tot_creds* to null for students who have not taken any course
- Instead of **sum**(*credits*), use:

  case
  when sum(*credits*) **is not null then sum**(*credits*)
  else 0
  end

Joined Relations

- **Join operations** take two relations and return as a result another relation
- A join operation is a Cartesian product which requires that tuples in the two relations match (under some condition).
- It also specifies the attributes that are present in the result of the join
- The join operations are typically used as subquery expressions in the **from** clause

Cross Join

- CROSS JOIN returns the Cartesian product of rows from tables in the join
  - Explicit

    select *

    from *employee* **cross join** *department*;
  - Implicit

    select *

    from *employee*, *department*;

Join operations – Example

- 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
  prereq information is missing for CS-315 and
  course information is missing for CS-347

Inner Join

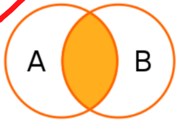
- *course* **inner join** *prereq*

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

- If specified as **natural**, the 2nd course_id field is skipped

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

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



Outer Join

- An extension of the join operation that avoids loss of information
- Computes the join and then adds tuples from one relation that does not match tuples in the other relation to the result of the join
- Uses *null* values

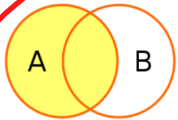
Left Outer Join

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

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

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

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



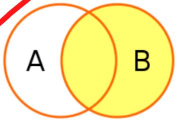
Right Outer Join

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

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

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



Joined Relations

- 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 $(A_1, A_1, \ldots, A_n)$

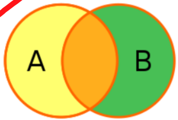
Full Outer Join

- *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

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

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



Joined Relations - Examples

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

course_id	*title*	*dept_name*	*credits*	*prere_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 (equi_join), and a natural join?
(no second course id)
- *course* **left outer join** *prereq* **on** *course.course_id = prereq.course_id*

course_id	*title*	*dept_name*	*credits*	*prere_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*

Joined Relations - Examples

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

course_id	*title*	*dept_name*	*credits*	*prere_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*	*prere_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

Views

- In some cases, it is not desirable for all users to see the entire logical model (that is, all the actual relations stored in the database.)
- Consider a person who needs to know an instructors name and department, but not the salary. This person should see a relation described, in SQL, by

  select *ID, name, dept_name*
  from *instructor*

- A **view** provides a mechanism to hide certain data from the view of certain users
- Any relation that is not of the conceptual model but is made visible to a user as a "virtual relation" is called a **view**.

View Definition

- A view is defined using the **create view** statement which has the form

  create view *v* **as** < query expression >

  where < query expression > is any legal SQL expression
- The view name is represented by *v*
- Once a view is defined, the view name can be used to refer to the virtual relation that the view generates
- View definition is not the same as creating a new relation by evaluating the query expression
  - Rather, a view definition causes the saving of an expression; the expression is substituted into queries using the view

Views can be Defined Using Other Views

Example Views

- 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* virtual relation, not persistent. ie faculty is calc (again?) when this
  where *dept_name* = 'Biology' query is called

- 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 on 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

View Expansion*

- A way to define the meaning of views defined in terms of other views
- Let view v_1 be defined by an expression e_1 that may itself contain uses of view relations
- View expansion of an expression repeats the following replacement step:

  repeat

  Find any view relation v_i in e_1

  Replace the view relation v_i by the expression defining v_i

  until no more view relations are present in e_1
- As long as the view definitions are not recursive, this loop will terminate

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 of the tuple

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

  into the *instructor* relation

  (original relation not the view)

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');
  - which department, if multiple departments in Taylor?
  - what if no department is in Taylor?
- 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

Materialized Views

- **Materializing a view**: create a physical table containing all the tuples in the result of the query defining the 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

Transactions

- Unit of work
- Atomic transaction
  - either fully executed or rolled back as if it never occurred
- Isolation from concurrent transactions
- Transactions begin implicitly
  - Ended by **commit work** or **rollback work**
- But default on most databases: each SQL statement commits automatically
  - Can turn off auto commit for a session (for example, using API)
  - In SQL:1999, can use: **begin atomic ... end**
    - Not supported on most databases

Integrity Constraints

- Integrity constraints guard against accidental damage to the database, by ensuring that authorized changes to the database do not result in a loss of data consistency
  - A checking account must have a balance greater than Rs. 10,000.00
  - A salary of a bank employee must be at least Rs. 250.00 an hour
  - A customer must have a (non-null) phone number

Integrity Constraints on a Single Relation

- **not null**
- **primary key**
- **unique**
- **check**(P), where P is a predicate

Not Null and Unique Constraints

- **not null**
  - Declare *name* and *budget* to be **not null**

    name **varchar**(20) **not null**

    budget **numeric**(12,2) **not null**
- **unique** $(A_1, A_2, \ldots, A_m)$
  - The unique specification states that the attributes $A_1, A_2, \ldots, A_m$ form a candidate key
  - Candidate keys are permitted to be null (in contrast to primary keys).

The check clause

- **check**(P), where P is a predicate
- Ensure that semester is one of fall, winter, spring or summer:

```
create table section (
    course_id varchar(8),
    sec_id varchar(8),
    semester varchar(6),
    year numeric(4,0),
    building varchar(15),
    room_number varchar(7),
    time slot id varchar(4),
    primary key (course_id, sec_id, semester, year),
    check (semester in ('Fall', 'Winter', 'Spring', 'Summer'))
);
```

Referential Integrity

- Ensures that a value that appears in one relation for a given set of attributes also appears for a certain set of attributes in another relation
- Example: If "Biology" is a department name appearing in one of the tuples in the instructor relation, then there exists a tuple in the *department* relation for "Biology"
- Let A be a set of attributes. Let R and S be two relations that contain attributes A and where A is the primary key of S. A is said to be a **foreign key** of R if for any values of A appearing in R these values also appear in S

Cascading Actions in Referential Integrity

- With cascading, you can define the actions that the Database Engine takes when a user tries to delete or update a key to which existing foreign keys point
- **create table** *course* (
  course_id **char**(5) **primary key**,
  title **varchar**(20),
  dept_name **varchar**(20) **references** *department*
)
- **create table** *course* (
  . . .
  dept_name **varchar**(20),
  foreign key (*dept_name*) **references** *department*
  on delete cascade
  on update cascade,
  . . .
)
- Alternative actions to cascade: **no action, set null, set default**

Integrity Constraint Violation During Transactions

- **create table** *person* (
  ID **char**(10),
  name **char**(40),
  mother **char**(10),
  father **char**(10),
  primary key *ID*,
  foreign key *father* **references** *person*,
  foreign key *mother* **references** *person*)
- How to insert a tuple without causing constraint violation?
  - Insert father and mother of a person before inserting person
  - OR, Set father and mother to null initially, update after inserting all persons (not possible if father and mother attributes declared to be **not null**)
  - OR Defer constraint checking (will discuss later)

Built-in Data Types in SQL

- **date**: Dates, containing a (4 digit) year, month and day
  - 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

Index Creation

- **create table** *student*
  (*ID* **varchar**(5),
  name **varchar**(20) **not null**,
  dept_name **varchar**(20),
  tot_cred **numeric** (3,0) **default** 0,
  primary key (*ID*))
- **create index** *studentID_index* **on** *student(ID)*
- Indices are data structures used to speed up access to records with specified values for index attributes
  select *
  from *student*
  where *ID* = '12345'
  - Can be executed by using the index to find the required record, without looking at all records of student
  - *More on indices in Chapter 9*

User-Defined Types

- **create type** construct in SQL creates user-defined type (alias, like typedef in C)

  create type *Dollars* **as numeric** (12,2) **final**

  - **create table** *department* (
    dept_name **varchar** (20),
    building **varchar** (15),
    budget Dollars);

Domains

- **create domain** construct in SQL-92 creates user-defined domain types

  create domain *person_name* **char**(20) **not null**

- Types and domains are similar
- Domains can have constraints, such as **not null**, specified on them

  create domain *degree_level* **varchar**(10)
  constraint *degree_level_test*
  check (**value in** ('Bachelors', 'Masters', 'Doctorate'));

Large-Object Types

- Large objects (photos, videos, CAD files, etc.) are stored as a *large object*:
  - **blob**: binary large object – object is a large collection of uninterpreted binary data (whose interpretation is left to an application outside of the database system)
  - **clob**: character large object – object is a large collection of character data
  - When a query returns a large object, a pointer is returned rather than the large object itself

Authorization

- Forms of authorization on parts of the database:
  - **Read** - allows reading, but not modification of data
  - **Insert** - allows insertion of new data, but not modification of existing data
  - **Update** - allows modification, but not deletion of data
  - **Delete** - allows deletion of data
- Forms of authorization to modify the database schema
  - **Index** - allows creation and deletion of indices
  - **Resources** - allows creation of new relations
  - **Alteration** - allows addition or deletion of attributes in a relation
  - **Drop** - allows deletion of relations

Authorization Specification in SQL

- The **grant** statement is used to confer authorization

  grant <privilege list>
  on <relation name or view name> **to** <user list>

- <user list> is:
  - a user-id
  - **public**, which allows all valid users the privilege granted
  - A role (more on this later)
- Granting a privilege on a view does not imply granting any privileges on the underlying relations
- The grantor of the privilege must already hold the privilege on the specified item (or be the database administrator)

Privileges in SQL

- **select**: allows read access to relation, or the ability to query using the view
  - Example: grant users U_1, U_2, and U_3 **select** authorization on the *instructor* relation:

    grant select on *instructor* **to** U_1, U_2, U_3
- **insert**: the ability to insert tuples
- **update**: the ability to update using the SQL update statement
- **delete**: the ability to delete tuples.
- **all privileges**: used as a short form for all the allowable privileges

Revoking Authorization in SQL

- The **revoke** statement is used to revoke authorization

  revoke <privilege list>
  on <relation name or view name> **from** <user list>

- Example:

  revoke select on *branch* **from** U_1, U_2, U_3

- <privilege-list> may be **all** to revoke all privileges the revokee may hold
- If <revokee-list> includes **public**, all users lose the privilege except those granted it explicitly
- If the same privilege was granted twice to the same user by different grantees, the user may retain the privilege after the revocation
- All privileges that depend on the privilege being revoked are also revoked

Roles

- **create role** *instructor*;
  - **grant** *instructor* **to** Amit;
- Privileges can be granted to roles:
  - **grant select on** takes **to** *instructor*;
- Roles can be granted to users, as well as to other roles
  - **create role** *teaching_assistant*
  - **grant** *teaching_assistant* **to** *instructor*;
  - *Instructor* inherits all privileges of *teaching_assistant*
- Chain of roles
  - **create role** dean;
  - **grant** *instructor* **to** dean;
  - **grant** *dean* **to** Satoshi;

Authorization on Views

- **create view** *geo_instructor* **as**
  (**select** *
  from *instructor*
  where *dept_name* = 'Geology');
  grant select on *geo_instructor* **to** *geo_staff*
- Suppose that a *geo_staff* member issues
  select *
  from *geo_instructor*;
- What if
  - *geo_staff* does not have permissions on *instructor*?
  - creator of view did not have some permissions on *instructor*?

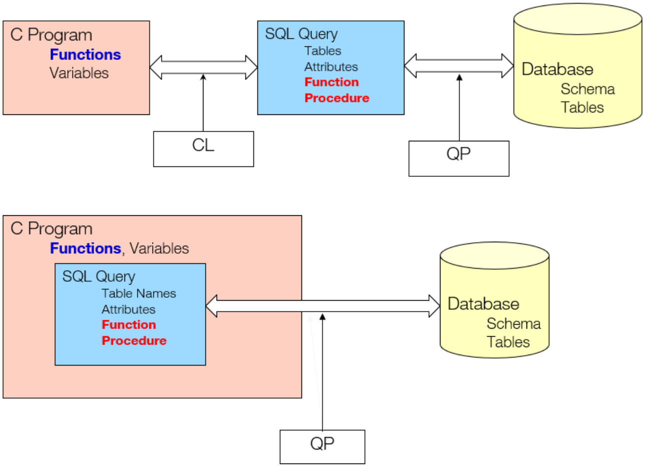
Other Authorization Features

- **references** privilege to create foreign key

  grant reference (*dept_name*) **on** *department* **to** Mariano;

  - why is this required?
- Transfer of privileges
  - **grant select on** *department* **to** Amit **with grant option**;
  - **revoke select on** *department* **from** Amit, Satoshi **cascade**;
  - **revoke select on** *department* **from** Amit, Satoshi **restrict**;

Native Language← →Query Language



Functions and Procedures

- Functions / Procedures and Control Flow Statements were added in SQL:1999
  - **Functions/Procedures** can be written in **SQL itself**, or in an **external programming language** (like C, Java)
  - Functions written in an external languages are particularly useful with specialized data types such as images and geometric objects
    - Example: Functions to check if polygons overlap, or to compare images for similarity
  - Some database systems support **table-valued functions**, which can return a relation as a result
- SQL:1999 also supports a rich set of imperative constructs, including **loops**, **if-then-else**, and **assignment**
- Many databases have proprietary procedural extensions to SQL that differ from SQL:1999

SQL Functions

- Define a function that, given the name of a department, returns the count of the number of instructors in that department:

```
create function dept_count (dept_name varchar(20))
    returns integer
    begin
    declare d_count integer; (local variable)
        select count (*) into d_count
        from instructor
        where instructor.dept_name = dept_name
    return d_cont;
    end
```

NO ';'

- The function *dept_count* can be used to find the department names and budget of all departments with more that 12 instructors:

```
select dept_name, budget
from department
where dept_count (dept_name ) > 12
```

SQL functions (2)

- Compound statement: **begin** . . . **end**
  May contain multiple SQL statements between **begin** and **end**.
- **returns** – indicates the variable-type that is returned (for example, integer)
- **return** – specifies the values that are to be returned as result of invoking the function
- SQL function are in fact **parameterized views** that generalize the regular notion of views by allowing parameters

Table Functions

- **Functions that return a relation as a result** added in SQL:2003
- Return all instructors in a given department:

```
create function instructor_of (dept_name char(20))
    returns table (
        ID varchar(5),
        name varchar(20),
        dept_name varchar(20)
        salary numeric(8, 2) )
    returns table
        (select ID, name, dept_name, salary
        from instructor
        where instructor.dept_name = instructor_of.dept_name)
```

- Usage

```
select *
from table (instructor_of ('Music'))
```

SQL Procedures

do not return anything but has parameters??

- The dept_count function could instead be written as procedure:

```
create procedure dept_count_proc (
        in dept_name varchar (20), out d_count integer)
    begin
        select count(*) into d_count
        from instructor
        where instructor.dept_name = dept_count_proc.dept_name
    end
```

no return statement

- Procedures can be invoked either from an SQL procedure or from embedded SQL, using the **call** statement.

```
declare d_count integer;
call dept_count_proc('Physics', d_count);
```

- Procedures and functions can be invoked also from dynamic SQL
- SQL:1999 allows **overloading** - more than one function/procedure of the same name as long as the number of arguments and / or the types of the arguments differ

Language Constructs for Procedures and Functions

- SQL supports constructs that gives it almost all the power of a general-purpose programming language.
  - *Warning*: **Most database systems implement their own variant of the standard syntax**
- Compound statement: **begin . . . end**
  - May contain multiple SQL statements between **begin** and **end**.
  - Local variables can be declared within a compound statements

Language Constructs (2): while and repeat

- **while** loop:

  while *boolean expression* **do**
  sequence of statements;
  end while;

- **repeat** loop: repeat will necessarily execute one time

  repeat
  sequence of statements;
  until *boolean expression*
  end repeat;

Language Constructs (3): for

- **for** loop
  - Permits iteration over all results of a query
- Find the budget of all departments:

declare *n* **integer default** 0;
for *r* **as**
    select *budget* **from** *department*
do
    set $n = n + r.budget$
end for;

Language Constructs (4): if-then-else

- Conditional statements
  - **if-then-else**
  - **case**
- **if-then-else** statement

  if *boolean expression* **then**
      sequence of statements;
  elseif *boolean expression* **then**
      sequence of statements;
  ...
  else
      sequence of statements;
  end if;

- The **if** statement supports the use of optional **elseif** clauses and a default **else** clause.
- Example procedure: registers student after ensuring classroom capacity is not exceeded
  - Returns 0 on success and -1 if capacity is exceeded
  - See book (page 177) for details

Language Constructs (5): Simple case

- Simple **case** statement

```
case variable
    when value1 then
        sequence of statements;
    when value2 then
        sequence of statements;
    . . .
    else
        sequence of statements;
end case;
```

- The **when** clause of the **case** statement defines the value that when satisfied determines the flow of control

Language Constructs (6): Searched case

- Searched **case** statement

  case
      when *sql-expression* = *value1* **then**
          sequence of statements;
      when *sql-expression* = *value2* **then**
          sequence of statements;
      ...
      else
          sequence of statements;
  end case;

- Any supported SQL expression can be used here. These expressions can contain references to variables, parameters, special registers, and more.

Language Constructs (7): Exception

- Signaling of exception conditions, and declaring handlers for exceptions

declare *out_of_classroom_seats* **condition**
declare **exit handler for** *out_of_classroom_seats*
begin
  ...
  signal *out_of_classroom_seats*
  ...
end

  - The handler here is **exit** – causes enclosing **begin** ... **end** to be terminate and exit
  - Other actions possible on exception

External Language Routines*

- SQL:1999 allows the definition of functions / procedures in an imperative programming language, (Java, C#, C or C++) which can be invoked from SQL queries
- Such functions can be more efficient than functions defined in SQL, and computations that cannot be carried out in SQL can be executed by these functions
- Declaring external language procedures and functions

```
create procedure dept_count_proc(
        in dept_name varchar(20),
        out count integer)
    language C
    external name '/usr/avi/bin/dept_count_proc'

create function dept_count(dept_name varchar(20))
returns integer
    language C
    external name '/usr/avi/bin/dept_count'
```

External Language Routines (3)*: Security

- To deal with security problems, we can do one of the following:
  - Use **sandbox** techniques
    - That is, use a safe language like Java, which cannot be used to access/damage other parts of the database code
  - Run external language functions/procedures in a separate process, with no access to the database process' memory
    - Parameters and results communicated via inter-process communication
- Both have performance overheads
- Many database systems support both above approaches as well as direct executing in database system address space

Trigger

- A **trigger** defines a set of actions that are performed in response to an **insert**, **update**, or **delete** operation on a specified table
  - When such an SQL operation is executed, the trigger is said to have been **activated**
  - Triggers are **optional**
  - Triggers are defined using the **create trigger** statement
- Triggers can be used
  - To enforce data integrity rules via referential constraints and check constraints
  - To cause updates to other tables, automatically generate or transform values for inserted or updated rows, or invoke functions to perform tasks such as issuing alerts
- To design a trigger mechanism, we must:
  - Specify the **events** / (like **update**, **insert**, or **delete**) for the trigger to executed
  - Specify the **time** (**BEFORE** or **AFTER**) of execution
  - Specify the **actions** to be taken when the trigger executes
- **Syntax of triggers may vary across systems**

Types of Triggers: BEFORE

- **BEFORE triggers**
  - Run before an **update**, or **insert**
  - Values that are being updated or inserted can be modified before the database is actually modified. You can use triggers that run before an update or insert to:
    - Check or modify values before they are actually updated or inserted in the database
      - Useful if user-view and internal database format differs
    - Run other non-database operations coded in user-defined functions
- **BEFORE DELETE triggers**
  - Run before a **delete**
    - Checks values (a raises an error, if necessary)

Types of Triggers (2): AFTER

- **AFTER triggers**
  - Run after an **update**, **insert**, or **delete**
  - You can use triggers that run after an update or insert to:
    - Update data in other tables
      - Useful for maintain relationships between data or keep audit trail
    - Check against other data in the table or in other tables
      - Useful to ensure data integrity when referential integrity constraints aren't appropriate, or
      - when table check constraints limit checking to the current table only
    - Run non-database operations coded in user-defined functions
      - Useful when issuing alerts or to update information outside the database

Row Level and Statement Level Triggers

There are two types of triggers based on the level at which the triggers are applied:

- **Row level triggers** are executed whenever a row is affected by the event on which the trigger is defined.
  - Let Employee be a table with 100 rows. Suppose an **update** statement is executed to increase the salary of each employee by 10%. Any row level **update** trigger configured on the table Employee will affect all the 100 rows in the table during this update.
- **Statement level triggers** perform a single action for all rows affected by a statement, instead of executing a separate action for each affected row.
  - Used for each **statement** instead of for each **row**
  - Uses **referencing old table** or **referencing new table** to refer to temporary tables called **transition tables** containing the affected rows
  - Can be more efficient when dealing with SQL statements that update a large number of rows

Triggering Events and Actions in SQL

- Triggering event can be an **insert, delete or update**
- Triggers on update can be restricted to specific attributes
  - For example, **after update of** *grade* **on** *takes*
- Values of attributes before and after an update can be referenced
  - **referencing old row as** : for deletes and updates
  - **referencing new row as** : for inserts and updates
- Triggers can be activated before an event, which can serve as extra constraints. For example, convert blank grades to null.

  create trigger *setnull_trigger* **before update of** *takes*
  referencing new row as *nrow*
  for each row
  when (*nrow.grade* = ' ')
    begin atomic
      set *nrow.grade* = **null**;
    end;

Trigger to Maintain credits_earned value

create trigger *credits_earned* **after update of** *grade* **on** (*takes*)
referencing new row as *nrow*
referencing old row as *orow*
for each row
when *nrow.grade* <>'F' **and** *nrow.grade* **is not null**
    and (*orow.grade* = 'F' **or** *orow.grade* **is null**)
begin atomic
    update *student*
    set *tot_cred*= *tot_cred* +
        (**select** *credits*
        from *course*
        where *course.course_id*=*nrow.course_id*)
    where *student.id* = *nrow.id*;
end;

SQL Not Equal (<>) Operator

In SQL, **not equal** operator is used to check whether two expressions are equal or not. If it's not equal, then the condition will be true, and it will return not matched records. Both **!=** and **<>** operators are not equal operators and will return the same result, but the **!=** operator is not an ISO standard.

How to use triggers?

- The optimal use of DML triggers is for short, simple, and easy to maintain write operations that act largely independent of an applications business logic.
- Typical and recommended uses of triggers include:
  - Logging changes to a history table
  - Auditing users and their actions against sensitive tables
  - Adding additional values to a table that may not be available to an application (due to security restrictions or other limitations), such as:
    - Login/user name
    - Time an operation occurs
    - Server/database name
  - Simple validation

Source: *SQL Server triggers: The good and the scary*

How to use triggers? (2)

- Triggers can become dangerous when:
  - There are too many
  - Trigger code becomes complex
  - Triggers go cross-server - across databases over network
  - Triggers call triggers
  - Recursive triggers are set to ON. This database-level setting is set to off by default
  - Functions, stored procedures, or views are in triggers
  - Iteration occurs

Source: *SQL Server triggers: The good and the scary*

Triggers : Functionality vs Performance (Cont.)

Case Study 1 (Cont.):

- **Problem:**
  - The row level AFTER INSERT trigger gets executed for each and every row inserted into the table **Vaccination**.
  - In order to check if the criteria are satisfied, the trigger will get executed every time a row is inserted, irrespective of whether the employee satisfies the criteria or not. That is, for every row inserted, the system has to perform a join of three tables.
  - This results in overhead operations and hence drastically reduces the throughput and thereby, the performance of the system.
- **Conclusion:**
  - Triggers are best suited for simple actions. More specifically, avoid joins involving multiple tables.

Triggers : Functionality vs Performance (Cont.)

Case Study 2:

- The database administrator of a bank sets up an AFTER UPDATE trigger to send an email notification to all customers of the bank whenever their KYC details are updated by a data entry clerk.
- Suppose the data entry clerk observes that she has made a data entry error in a customer's KYC information while updating it. An email notification would have already been dispatched to the customer even though the clerk can correct the error as soon as she notices it.
- This will lead to unnecessary confusion for the customer.

Triggers : Functionality vs Performance (Cont.)

Case Study 2 (Cont.):

- **Problem:**
  - The clerk immediately realises her mistake and a database ROLLBACK is done to the previous consistent state but the sent emails cannot be recalled in most cases.
- **Conclusion:**
  - Operations performed by triggers outside the database system like sending emails, writing to files etc cannot be rolled back. Thus, in many cases, it is better to avoid using triggers for events that are external to the database.