



SQL AND PL/SQL

Database System Concepts, 6th Ed.

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Outline

- **SQL:** Characteristics and advantages,
- SQL Data Types and Literals,
- DDL, DML, DCL, TCL,
- SQL Operators,
- Tables: Creating, Modifying, Deleting,
- Views: Creating, Dropping, Updating using Views,
- Indexes,
- SQL DML Queries: SELECT Query and clauses,
- Set Operations, Predicates and Joins, Set membership,
- Tuple Variables, Set comparison,
- Ordering of Tuples,
- Aggregate Functions,
- Nested Queries,
- Database Modification using SQL Insert, Update and Delete Queries.
- **PL/SQL:** concept of Stored Procedures & Functions, Cursors, Triggers, Assertions, roles and privileges , Embedded SQL, Dynamic SQL.



Introduction to SQL

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Outline

- Overview of The SQL Query Language
- Data Definition
- Basic Query Structure
- Additional Basic Operations
- Set Operations
- Null Values
- Aggregate Functions
- Nested Subqueries
- Modification of the Database



History

- IBM Sequel language developed as part of System R project at the IBM San Jose Research Laboratory
- Renamed Structured Query Language (SQL)
- ANSI and ISO standard SQL:
 - SQL-86
 - SQL-89
 - SQL-92
 - SQL:1999 (language name became Y2K compliant!)
 - SQL:2003
- Commercial systems offer most, if not all, SQL-92 features, plus varying feature sets from later standards and special proprietary features.
 - Not all examples here may work on your particular system.



Data Definition Language

The SQL data-definition language (DDL) allows the specification of information about relations, including:

- The schema for each relation.
- The domain of values associated with each attribute.
- Integrity constraints
- And as we will see later, also other information such as
 - The set of indices to be maintained for each relations.
 - Security and authorization information for each relation.
 - The physical storage structure of each relation on disk.



Domain Types in SQL

- **char(*n*)**. Fixed length character string, with user-specified length *n*.
- **varchar(*n*)**. Variable length character strings, with user-specified maximum length *n*.
- **int**. Integer (a finite subset of the integers that is machine-dependent).
- **smallint**. Small integer (a machine-dependent subset of the integer domain type).
- **numeric(*p,d*)**. Fixed point number, with user-specified precision of *p* digits, with *d* digits to the right of decimal point. (ex., **numeric(3,1)**, allows 44.5 to be stored exactly, but not 444.5 or 0.32)
- **real, double precision**. Floating point and double-precision floating point numbers, with machine-dependent precision.
- **float(*n*)**. Floating point number, with user-specified precision of at least *n* digits.
- More are covered in Chapter 4.



Create Table Construct

- An SQL relation is defined using the **create table** command:

```
create table r (A1 D1, A2 D2, ..., An Dn,  
                (integrity-constraint1),  
                ...,  
                (integrity-constraintk))
```

- *r* is the name of the relation
 - each *A*_{*i*} is an attribute name in the schema of relation *r*
 - *D*_{*i*} is the data type of values in the domain of attribute *A*_{*i*}
-
- Example:

```
create table instructor (  
    ID          char(5),  
    name       varchar(20),  
    dept_name varchar(20),  
    salary    numeric(8,2))
```



Integrity Constraints in Create Table

- not null
- primary key (A_1, \dots, A_n)
- foreign key (A_m, \dots, A_n) references r

Example:

```
create table instructor (  
    ID          char(5),  
    name       varchar(20) not null,  
    dept_name varchar(20),  
    salary     numeric(8,2),  
    primary key (ID),  
    foreign key (dept_name) references department);
```

primary key declaration on an attribute automatically ensures **not null**



And a Few More Relation Definitions

- **create table** *student* (
 ID **varchar**(5),
 name **varchar**(20) not null,
 dept_name **varchar**(20),
 tot_cred **numeric**(3,0),
 primary key (*ID*),
 foreign key (*dept_name*) **references** *department*);

- **create table** *takes* (
 ID **varchar**(5),
 course_id **varchar**(8),
 sec_id **varchar**(8),
 semester **varchar**(6),
 year **numeric**(4,0),
 grade **varchar**(2),
 primary key (*ID*, *course_id*, *sec_id*, *semester*, *year*) ,
 foreign key (*ID*) **references** *student*,
 foreign key (*course_id*, *sec_id*, *semester*, *year*) **references** *section*);

- Note: *sec_id* can be dropped from primary key above, to ensure a student cannot be registered for two sections of the same course in the same semester



And more still

- **create table** *course* (
 course_id **varchar**(8),
 title **varchar**(50),
 dept_name **varchar**(20),
 credits **numeric**(2,0),
 primary key (*course_id*),
 foreign key (*dept_name*) **references** *department*);



Updates to tables

■ Insert

- **insert into** *instructor* **values** ('10211', 'Smith', 'Biology', 66000);

■ Delete

- Remove all tuples from the *student* relation
 - ▶ **delete from** *student*

■ Drop Table

- **drop table** *r*

■ Alter

- **alter table** *r* **add** *A D*
 - ▶ where *A* is the name of the attribute to be added to relation *r* and *D* is the domain of *A*.
 - ▶ All existing tuples in the relation are assigned *null* as the value for the new attribute.
- **alter table** *r* **drop** *A*
 - ▶ where *A* is the name of an attribute of relation *r*
 - ▶ Dropping of attributes not supported by many databases.



Basic Query Structure

- A typical SQL query has the form:

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

- A_i represents an attribute
 - R_i represents a relation
 - P is a predicate.
- The result of an SQL query is a relation.



The select Clause

- The **select** clause lists the attributes desired in the result of a query
 - corresponds to the projection operation of the relational algebra
- Example: find the names of all instructors:

```
select name  
from instructor
```
- NOTE: SQL names are case insensitive (i.e., you may use upper- or lower-case letters.)
 - E.g., *Name* \equiv *NAME* \equiv *name*
 - Some people use upper case wherever we use bold font.



The select Clause (Cont.)

- SQL allows duplicates in relations as well as in query results.
- To force the elimination of duplicates, insert the keyword **distinct** after select.
- Find the department names of all instructors, and remove duplicates

```
select distinct dept_name  
from instructor
```

- The keyword **all** specifies that duplicates should not be removed.

```
select all dept_name  
from instructor
```



The select Clause (Cont.)

- An asterisk in the select clause denotes “all attributes”

```
select *  
from instructor
```

- An attribute can be a literal with no **from** clause

```
select '437'
```

- Results is a table with one column and a single row with value “437”
- Can give the column a name using:

```
select '437' as FOO
```

- An attribute can be a literal with **from** clause

```
select 'A'  
from instructor
```

- Result is a table with one column and N rows (number of tuples in the *instructors* table), each row with value “A”



The select Clause (Cont.)

- The **select** clause can contain arithmetic expressions involving the operation, +, -, *, and /, and operating on constants or attributes of tuples.

- The query:

```
select ID, name, salary/12  
from instructor
```

would return a relation that is the same as the *instructor* relation, except that the value of the attribute *salary* is divided by 12.

- Can rename “*salary/12*” using the **as** clause:

```
select ID, name, salary/12 as monthly_salary
```



The where Clause

- The **where** clause specifies conditions that the result must satisfy
 - Corresponds to the selection predicate of the relational algebra.
- To find all instructors in Comp. Sci. dept

```
select name  
from instructor  
where dept_name = 'Comp. Sci.'
```

- Comparison results can be combined using the logical connectives **and**, **or**, and **not**
 - To find all instructors in Comp. Sci. dept with salary > 80000

```
select name  
from instructor  
where dept_name = 'Comp. Sci.' and salary > 80000
```

- Comparisons can be applied to results of arithmetic expressions.



The from Clause

- The **from** clause lists the relations involved in the query
 - Corresponds to the Cartesian product operation of the relational algebra.

- Find the Cartesian product *instructor X teaches*

```
select *  
from instructor, teaches
```

- generates every possible instructor - teaches pair, with all attributes from both relations.
 - For common attributes (e.g., *ID*), the attributes in the resulting table are renamed using the relation name (e.g., *instructor.ID*)
- Cartesian product not very useful directly, but useful combined with where-clause condition (selection operation in relational algebra).



Cartesian Product

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

teaches

<i>ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
10101	CS-101	1	Fall	2009
10101	CS-315	1	Spring	2010
10101	CS-347	1	Fall	2009
12121	FIN-201	1	Spring	2010
15151	MU-199	1	Spring	2010
22222	PHY-101	1	Fall	2009

<i>Inst.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	2009
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2009
10101	Srinivasan	Comp. Sci.	65000	12121	FIN-201	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	15151	MU-199	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	22222	PHY-101	1	Fall	2009
...
...
12121	Wu	Finance	90000	10101	CS-101	1	Fall	2009
12121	Wu	Finance	90000	10101	CS-315	1	Spring	2010
12121	Wu	Pinance	90000	10101	CS-347	1	Fall	2009
12121	Wu	Pinance	90000	12121	FIN-201	1	Spring	2010
12121	Wu	Finance	90000	15151	MU-199	1	Spring	2010
12121	Wu	Pinance	90000	22222	PHY-101	1	Fall	2009
...
...



Examples

- Find the names of all instructors who have taught some course and the course_id
 - **select** *name, course_id*
from *instructor, teaches*
where *instructor.ID = teaches.ID*

- Find the names of all instructors in the Art department who have taught some course and the course_id
 - **select** *name, course_id*
from *instructor, teaches*
where *instructor.ID = teaches.ID* **and** *instructor.dept_name = 'Art'*



The Rename Operation

- The SQL allows renaming relations and attributes using the **as** clause:

old-name as new-name

- Find the names of all instructors who have a higher salary than some instructor in 'Comp. Sci'.

- **select distinct** *T.name*
from *instructor as T, instructor as S*
where *T.salary > S.salary and S.dept_name = 'Comp. Sci.'*

- Keyword **as** is optional and may be omitted

instructor as T \equiv *instructor T*



Cartesian Product Example

- Relation *emp-super*

<i>person</i>	<i>supervisor</i>
Bob	Alice
Mary	Susan
Alice	David
David	Mary

- Find the supervisor of “Bob”
- Find the supervisor of the supervisor of “Bob”
- Find ALL the supervisors (direct and indirect) of “Bob”



String Operations

- SQL includes a string-matching operator for comparisons on character strings. The operator **like** uses patterns that are described using two special characters:
 - percent (%). The % character matches any substring.
 - underscore (_). The _ character matches any character.
- Find the names of all instructors whose name includes the substring “dar”.

```
select name  
from instructor  
where name like '%dar%'
```

- Match the string “100%”

```
like '100 \% ' escape '\'
```

in that above we use backslash (\) as the escape character.



String Operations (Cont.)

- Patterns are case sensitive.
- Pattern matching examples:
 - 'Intro%' matches any string beginning with "Intro".
 - '%Comp%' matches any string containing "Comp" as a substring.
 - '___' matches any string of exactly three characters.
 - '___ %' matches any string of at least three characters.

- SQL supports a variety of string operations such as
 - concatenation (using "||")
 - converting from upper to lower case (and vice versa)
 - finding string length, extracting substrings, etc.



Ordering the Display of Tuples

- List in alphabetic order the names of all instructors

```
select distinct name  
from instructor  
order by name
```

- We may specify **desc** for descending order or **asc** for ascending order, for each attribute; ascending order is the default.
 - Example: **order by** *name desc*
- Can sort on multiple attributes
 - Example: **order by** *dept_name, name*



Where Clause Predicates

- SQL includes a **between** comparison operator
- Example: Find the names of all instructors with salary between \$90,000 and \$100,000 (that is, \geq \$90,000 and \leq \$100,000)
 - **select** *name*
from *instructor*
where *salary* **between** 90000 **and** 100000
- Tuple comparison
 - **select** *name, course_id*
from *instructor, teaches*
where (*instructor.ID, dept_name*) = (*teaches.ID, 'Biology'*);



Duplicates

- In relations with duplicates, SQL can define how many copies of tuples appear in the result.
- **Multiset** versions of some of the relational algebra operators - given multiset relations r_1 and r_2 :
 1. $\sigma_{\theta}(r_1)$: If there are c_1 copies of tuple t_1 in r_1 , and t_1 satisfies selections σ_{θ} , then there are c_1 copies of t_1 in $\sigma_{\theta}(r_1)$.
 2. $\Pi_A(r)$: For each copy of tuple t_1 in r_1 , there is a copy of tuple $\Pi_A(t_1)$ in $\Pi_A(r_1)$ where $\Pi_A(t_1)$ denotes the projection of the single tuple t_1 .
 3. $r_1 \times r_2$: If there are c_1 copies of tuple t_1 in r_1 and c_2 copies of tuple t_2 in r_2 , there are $c_1 \times c_2$ copies of the tuple $t_1 \cdot t_2$ in $r_1 \times r_2$



Duplicates (Cont.)

- Example: Suppose multiset relations $r_1 (A, B)$ and $r_2 (C)$ are as follows:

$$r_1 = \{(1, a) (2, a)\} \quad r_2 = \{(2), (3), (3)\}$$

- Then $\Pi_B(r_1)$ would be $\{(a), (a)\}$, while $\Pi_B(r_1) \times r_2$ would be $\{(a,2), (a,2), (a,3), (a,3), (a,3), (a,3)\}$

- SQL duplicate semantics:

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

is equivalent to the *multiset* version of the expression:

$$\prod_{A_1, A_2, \dots, A_n} (\sigma_P (r_1 \times r_2 \times \dots \times r_m))$$



Set Operations

- Find courses that ran in Fall 2009 or in Spring 2010

(select *course_id* from *section* where *sem* = 'Fall' and *year* = 2009)

union

(select *course_id* from *section* where *sem* = 'Spring' and *year* = 2010)

- Find courses that ran in Fall 2009 and in Spring 2010

(select *course_id* from *section* where *sem* = 'Fall' and *year* = 2009)

intersect

(select *course_id* from *section* where *sem* = 'Spring' and *year* = 2010)

- Find courses that ran in Fall 2009 but not in Spring 2010

(select *course_id* from *section* where *sem* = 'Fall' and *year* = 2009)

except

(select *course_id* from *section* where *sem* = 'Spring' and *year* = 2010)



Set Operations (Cont.)

- Find the salaries of all instructors that are less than the largest salary.
 - **select distinct** *T.salary*
from *instructor* **as** *T*, *instructor* **as** *S*
where *T.salary* < *S.salary*

- Find all the salaries of all instructors
 - **select distinct** *salary*
from *instructor*

- Find the largest salary of all instructors.
 - **(select** “second query”)
except
(select “first query”)



Set Operations (Cont.)

- Set operations **union**, **intersect**, and **except**
 - Each of the above operations automatically eliminates duplicates
- To retain all duplicates use the corresponding multiset versions **union all**, **intersect all** and **except all**.
- Suppose a tuple occurs m times in r and n times in s , then, it occurs:
 - $m + n$ times in r **union all** s
 - $\min(m, n)$ times in r **intersect all** s
 - $\max(0, m - n)$ times in r **except all** s



Null Values

- It is possible for tuples to have a null value, denoted by *null*, for some of their attributes
- *null* signifies an unknown value or that a value does not exist.
- The result of any arithmetic expression involving *null* is *null*
 - Example: $5 + \textit{null}$ returns null
- The predicate **is null** can be used to check for null values.
 - Example: Find all instructors whose salary is null.

```
select name
from instructor
where salary is null
```



Null Values and Three Valued Logic

- Three values - *true*, *false*, *unknown*
- Any comparison with *null* returns *unknown*
 - Example: $5 < null$ or $null <> null$ or $null = null$
- Three-valued logic using the value *unknown*:
 - OR: $(unknown \text{ or } true) = true$,
 $(unknown \text{ or } false) = unknown$
 $(unknown \text{ or } unknown) = unknown$
 - AND: $(true \text{ and } unknown) = unknown$,
 $(false \text{ and } unknown) = false$,
 $(unknown \text{ and } unknown) = unknown$
 - NOT: $(\text{not } unknown) = unknown$
 - “*P* is unknown” evaluates to true if predicate *P* evaluates to *unknown*
- Result of **where** clause predicate is treated as *false* if it evaluates to *unknown*



Aggregate Functions

- These functions operate on the multiset of values of a column of a relation, and return a value

avg: average value

min: minimum value

max: maximum value

sum: sum of values

count: number of values



Aggregate Functions (Cont.)

- Find the average salary of instructors in the Computer Science department
 - **select avg** (*salary*)
from *instructor*
where *dept_name*= 'Comp. Sci.';
- Find the total number of instructors who teach a course in the Spring 2010 semester
 - **select count** (**distinct** *ID*)
from *teaches*
where *semester* = 'Spring' **and** *year* = 2010;
- Find the number of tuples in the *course* relation
 - **select count** (*)
from *course*;



Aggregate Functions – Group By

- Find the average salary of instructors in each department
 - **select** *dept_name*, **avg** (*salary*) **as** *avg_salary*
from *instructor*
group by *dept_name*;

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
76766	Crick	Biology	72000
45565	Katz	Comp. Sci.	75000
10101	Srinivasan	Comp. Sci.	65000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000
12121	Wu	Finance	90000
76543	Singh	Finance	80000
32343	El Said	History	60000
58583	Califieri	History	62000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
22222	Einstein	Physics	95000

<i>dept_name</i>	<i>avg_salary</i>
Biology	72000
Comp. Sci.	77333
Elec. Eng.	80000
Finance	85000
History	61000
Music	40000
Physics	91000



Aggregation (Cont.)

- Attributes in **select** clause outside of aggregate functions must appear in **group by** list
 - */* erroneous query */*
select *dept_name, ID, avg (salary)*
from *instructor*
group by *dept_name;*



Aggregate Functions – Having Clause

- Find the names and average salaries of all departments whose average salary is greater than 42000

```
select dept_name, avg (salary)
from instructor
group by dept_name
having avg (salary) > 42000;
```

Note: predicates in the **having** clause are applied after the formation of groups whereas predicates in the **where** clause are applied before forming groups



Null Values and Aggregates

- Total all salaries

```
select sum (salary)  
from instructor
```

- Above statement ignores null amounts
- Result is *null* if there is no non-null amount
- All aggregate operations except **count(*)** ignore tuples with null values on the aggregated attributes
- What if collection has only null values?
 - count returns 0
 - all other aggregates return null



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  $A_1, A_2, \dots, A_n$   
from  $r_1, r_2, \dots, r_m$   
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:

$B <\text{operation}> (\text{subquery})$

Where B is an attribute and $<\text{operation}>$ to be defined later.



Subqueries in the Where Clause



Subqueries in the Where Clause

- A common use of subqueries is to perform tests:
 - For set membership
 - For set comparisons
 - For set cardinality.



Set Membership

- Find courses offered in Fall 2009 and in Spring 2010

```
select distinct course_id
from section
where semester = 'Fall' and year= 2009 and
       course_id in (select course_id
                       from section
                       where semester = 'Spring' and year= 2010);
```

- Find courses offered in Fall 2009 but not in Spring 2010

```
select distinct course_id
from section
where semester = 'Fall' and year= 2009 and
       course_id not in (select course_id
                             from section
                             where semester = 'Spring' and year= 2010);
```



Set Membership (Cont.)

- Find the total number of (distinct) students who have taken course sections taught by the instructor with *ID* 10101

```
select count (distinct ID)  
from takes  
where (course_id, sec_id, semester, year) in  
      (select course_id, sec_id, semester, year  
       from teaches  
       where teaches.ID= 10101);
```

- Note: Above query can be written in a much simpler manner. The formulation above is simply to illustrate SQL features.



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

- $F \langle \text{comp} \rangle \text{some } r \Leftrightarrow \exists t \in r \text{ such that } (F \langle \text{comp} \rangle t)$
Where $\langle \text{comp} \rangle$ can be: $<$, \leq , $>$, $=$, \neq

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

(read: 5 < some tuple in the relation)

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

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

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

$(= \text{some}) \equiv \text{in}$

However, $(\neq \text{some}) \not\equiv \text{not in}$



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

- $F \text{ <comp> all } r \Leftrightarrow \forall t \in r (F \text{ <comp> } t)$

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

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

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

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

$(\neq \text{all}) \equiv \text{not in}$

However, $(= \text{all}) \not\equiv \text{in}$



Test for Empty Relations

- 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 that $X - Y = \emptyset \Leftrightarrow X \subseteq Y$
- *Note:* Cannot write this query using = **all** and its variants



Test for Absence of Duplicate Tuples

- 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 Form Clause



Subqueries in the Form 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;
```



Complex Queries using With Clause

- Find all departments where the total salary is greater than the average of the total salary at all departments

```
with dept_total (dept_name, value) as  
    (select dept_name, sum(salary)  
    from instructor  
    group by dept_name),  
dept_total_avg(value) as  
    (select avg(value)  
    from dept_total)  
select dept_name  
from dept_total, dept_total_avg  
where dept_total.value > dept_total_avg.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 (Cont.)

- 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:
 1. First, compute **avg** (*salary*) and find all tuples to delete
 2. 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 (Cont.)

- 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_cred` value for all students

update *student S*

set *tot_cred* = (**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_cred* 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



PL - Advanced SQL

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Outline

- Accessing SQL From a Programming Language
- Functions and Procedural Constructs
- Triggers
- Recursive Queries
- Advanced Aggregation Features
- OLAP



Accessing SQL From a Programming Language

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Accessing SQL From a Programming Language

- API (application-program interface) for a program to interact with a database server
- Application makes calls to
 - Connect with the database server
 - Send SQL commands to the database server
 - Fetch tuples of result one-by-one into program variables
- Various tools:
 - JDBC (Java Database Connectivity) works with Java
 - ODBC (Open Database Connectivity) works with C, C++, C#, and Visual Basic. Other API's such as ADO.NET sit on top of ODBC
 - Embedded SQL



JDBC

- **JDBC** is a Java API for communicating with database systems supporting SQL.
- JDBC supports a variety of features for querying and updating data, and for retrieving query results.
- JDBC also supports metadata retrieval, such as querying about relations present in the database and the names and types of relation attributes.
- Model for communicating with the database:
 - Open a connection
 - Create a “statement” object
 - Execute queries using the Statement object to send queries and fetch results
 - Exception mechanism to handle errors



ODBC

- Open DataBase Connectivity (ODBC) standard
 - standard for application program to communicate with a database server.
 - application program interface (API) to
 - ▶ open a connection with a database,
 - ▶ send queries and updates,
 - ▶ get back results.
- Applications such as GUI, spreadsheets, etc. can use ODBC



Embedded SQL

- The SQL standard defines embeddings of SQL in a variety of programming languages such as C, C++, Java, Fortran, and PL/1,
- A language to which SQL queries are embedded is referred to as a **host language**, and the SQL structures permitted in the host language comprise *embedded SQL*.
- The basic form of these languages follows that of the System R embedding of SQL into PL/1.
- **EXEC SQL** statement is used to identify embedded SQL request to the preprocessor

EXEC SQL <embedded SQL statement >;

Note: this varies by language:

- In some languages, like COBOL, the semicolon is replaced with END-EXEC
- In Java embedding uses `# SQL { };`



Embedded SQL (Cont.)

- Before executing any SQL statements, the program must first connect to the database. This is done using:

```
EXEC-SQL connect to server user user-name using password;
```

Here, *server* identifies the server to which a connection is to be established.

- Variables of the host language can be used within embedded SQL statements. They are preceded by a colon (:) to distinguish from SQL variables (e.g., *:credit_amount*)
- Variables used as above must be declared within DECLARE section, as illustrated below. The syntax for declaring the variables, however, follows the usual host language syntax.

```
EXEC-SQL BEGIN DECLARE SECTION}
```

```
    int credit-amount ;
```

```
EXEC-SQL END DECLARE SECTION;
```



Embedded SQL (Cont.)

- To write an embedded SQL query, we use the **declare c cursor for <SQL query>** statement. The variable *c* is used to identify the query
- Example:
 - From within a host language, find the ID and name of students who have completed more than the number of credits stored in variable `credit_amount` in the host language
 - Specify the query in SQL as follows:

EXEC SQL

```
declare c cursor for  
select ID, name  
from student  
where tot_cred > :credit_amount
```

END_EXEC



Embedded SQL (Cont.)

- Example:
 - From within a host language, find the ID and name of students who have completed more than the number of credits stored in variable `credit_amount` in the host language
- Specify the query in SQL as follows:

EXEC SQL

```
declare c cursor for  
select ID, name  
from student  
where tot_cred > :credit_amount
```

END_EXEC

- The variable `c` (used in the cursor declaration) is used to identify the query



Embedded SQL (Cont.)

- The **open** statement for our example is as follows:

```
EXEC SQL open c ;
```

This statement causes the database system to execute the query and to save the results within a temporary relation. The query uses the value of the host-language variable *credit-amount* at the time the **open** statement is executed.

- The fetch statement causes the values of one tuple in the query result to be placed on host language variables.

```
EXEC SQL fetch c into :si, :sn END_EXEC
```

Repeated calls to fetch get successive tuples in the query result



Embedded SQL (Cont.)

- A variable called SQLSTATE in the SQL communication area (SQLCA) gets set to '02000' to indicate no more data is available
- The **close** statement causes the database system to delete the temporary relation that holds the result of the query.

EXEC SQL close c ;

Note: above details vary with language. For example, the Java embedding defines Java iterators to step through result tuples.



Updates Through Embedded SQL

- Embedded SQL expressions for database modification (**update**, **insert**, and **delete**)
- Can update tuples fetched by cursor by declaring that the cursor is for update

EXEC SQL

```
declare c cursor for  
select *  
from instructor  
where dept_name = 'Music'  
for update
```

- We then iterate through the tuples by performing **fetch** operations on the cursor (as illustrated earlier), and after fetching each tuple we execute the following code:

```
update instructor  
set salary = salary + 1000  
where current of c
```



Extensions to SQL

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Functions and Procedures

- SQL:1999 supports functions and procedures
 - Functions/procedures can be written in SQL itself, or in an external programming language (e.g., 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, 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;  
    select count ( * ) into d_count  
    from instructor  
    where instructor.dept_name = dept_name  
    return d_count;  
end
```

- 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 (Cont.)

- Compound statement: **begin ... end**
 - May contain multiple SQL statements between **begin** and **end**.
- **returns** -- indicates the variable-type that is returned (e.g., 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

- SQL:2003 added functions that return a relation as a result
- Example: 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))

return 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

- 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

- 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 more than one function/procedure of the same name (called name **overloading**), as long as the number of arguments differ, or at least the types of the arguments differ



Language Constructs for Procedures & 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 below.
- Compound statement: **begin ... end**,
 - May contain multiple SQL statements between **begin** and **end**.
 - Local variables can be declared within a compound statements
- **While** and **repeat** statements:
 - **while** boolean expression **do**
 sequence of statements ;
end while
 - **repeat**
 sequence of statements ;
until boolean expression
end repeat



Language Constructs (Cont.)

- **For** loop
 - Permits iteration over all results of a query
- Example: 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 (Cont.)

- Conditional statements (**if-then-else**)
SQL:1999 also supports a **case** statement similar to C case statement
- 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
- 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 exited
 - Other actions possible on exception



External Language Routines

- SQL:1999 permits the use of functions and procedures written in other languages such as C or C++
- 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

- SQL:1999 allows the definition of procedures in an imperative programming language, (Java, C#, C or C++) which can be invoked from SQL queries.
- Functions defined in this fashion 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 (Cont.)

- Benefits of external language functions/procedures:
 - more efficient for many operations, and more expressive power.
- Drawbacks
 - Code to implement function may need to be loaded into database system and executed in the database system's address space.
 - ▶ risk of accidental corruption of database structures
 - ▶ security risk, allowing users access to unauthorized data
 - There are alternatives, which give good security at the cost of potentially worse performance.
 - Direct execution in the database system's space is used when efficiency is more important than security.



Security with External Language Routines

- To deal with security problems, we can do on 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.



Triggers

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Triggers

- A **trigger** is a statement that is executed automatically by the system as a side effect of a modification to the database.
- To design a trigger mechanism, we must:
 - Specify the conditions under which the trigger is to be executed.
 - Specify the actions to be taken when the trigger executes.
- Triggers introduced to SQL standard in SQL:1999, but supported even earlier using non-standard syntax by most databases.
 - **Syntax illustrated here may not work exactly on your database system; check the system manuals**



Triggering Events and Actions in SQL

- Triggering event can be **insert**, **delete** or **update**
- Triggers on update can be restricted to specific attributes
 - For example, **after update of *takes* on *grade***
- 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 `takes` on (`grade`)**
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;



Statement Level Triggers

- Instead of executing a separate action for each affected row, a single action can be executed for all rows affected by a transaction
 - Use **for each statement** instead of **for each row**
 - Use **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



When Not To Use Triggers

- Triggers were used earlier for tasks such as
 - Maintaining summary data (e.g., total salary of each department)
 - Replicating databases by recording changes to special relations (called **change** or **delta** relations) and having a separate process that applies the changes over to a replica
- There are better ways of doing these now:
 - Databases today provide built in materialized view facilities to maintain summary data
 - Databases provide built-in support for replication
- Encapsulation facilities can be used instead of triggers in many cases
 - Define methods to update fields
 - Carry out actions as part of the update methods instead of through a trigger



When Not To Use Triggers (Cont.)

- Risk of unintended execution of triggers, for example, when
 - Loading data from a backup copy
 - Replicating updates at a remote site
 - Trigger execution can be disabled before such actions.
- Other risks with triggers:
 - Error leading to failure of critical transactions that set off the trigger
 - Cascading execution