Part 8: SQL I

Database System Concepts, 7th Ed.

Data Definition Language

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

- The schema for each relation
- The type of values associated with each attribute
- The Integrity constraints
- The set of indices to be maintained for each relation
- 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 (32 bits, from -2^{31} to 2^{31}-1)
- **smallint.** Small integer (16 bits, from -2^{15} to 2^{15}-1)
- **numeric(p,d).** Fixed point number, with user-specified precision of *p* digits, with *d* digits to the right of decimal point. (e.g., **numeric**(3,1), allows 44.5 to be stores exactly, but not 444.5 or 0.32)
- **real, double precision.** Floating point and double-precision floating point numbers S × 2^E (32 bits for real and 64 bits for double precision. The exponent is either 11 bit (double precision) or 8 bit (real). The Significand uses the remaining places with a sign bit for the number, 52 bits in case of double precision & 23 bits in case of real)

Create Table Construct

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

  create table *r*

  $(A_1\ D_1,\ A_2\ D_2,\ ...,\ A_n\ D_n\ ,$
  (integrity-constraint$_1$),
  ...,
  (integrity-constraint$_k$))

  - *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

- Types of integrity constraints
  - **primary key** (A_1, ..., A_n)
  - **foreign key** (A_m, ..., A_n) **references** *r*
  - **not null**
- SQL prevents any update to the database that violates an integrity constraint
- 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);
```

Integrity Constraints

-
  ```
  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);
  ```

Integrity Constraints

```
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*
    - Not only delete all tuples of *r*, but also the schema for *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 systems

Basic Query Structure

- A typical SQL query has the form:

  select A_1, A_2, ..., A_n
  from r_1, r_2, ..., 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* ≡ *NAME* ≡ *name*

The select Clause

- SQL allows duplicates 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

- 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

- 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 with the value of the attribute *salary* 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.'

- SQL allows the use of the logical connectives **and, or,** and **not**
- The operands of the logical connectives can be expressions involving the comparison operators <, <=, >, >=, =, and <>
- Comparisons can be applied to results of arithmetic expressions
- To find all instructors in "Comp. Sci." dept with salary > 80000

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

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)

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 at least one instructor in ‘Biology’

  - **select distinct** *T.name*
    from *instructor* **as** *T, instructor* **as** *S*
    where *T.salary* > *S.salary* **and** *S.dept_name* = ‘Biology’

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

  instructor **as** *T* ≡ *instructor T*

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 all strings beginning with “ab%cd”

  like ‘ab\%cd%'

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

String Operations

- 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

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, ≥ $90,000 and ≤ $100,000); may use

  -
    ```
    select name
    from instructor
    where salary between 90000 and 100000
    ```

  Instead of

  -
    ```
    select name
    from instructor
    where salary <= 100000 and salary >= 90000
    ```

Set Operations

- Find courses that ran in Fall 2017 or in Spring 2018

```
(select course_id  from section where sem = 'Fall' and year = 2017)
union
(select course_id  from section where sem = 'Spring' and year = 2018)
```

- Find courses that ran in Fall 2017 and in Spring 2018

```
(select course_id  from section where sem = 'Fall' and year = 2017)
intersect
(select course_id  from section where sem = 'Spring' and year = 2018)
```

- Find courses that ran in Fall 2017 but not in Spring 2018

```
(select course_id  from section where sem = 'Fall' and year = 2017)
except
(select course_id  from section where sem = 'Spring' and year = 2018)
```

Set Operations

- Set operations **union**, **intersect**, and **except**
  - Each of the above operations automatically eliminates duplicates
- To retain all duplicates use the
  - **union all**
  - **intersect all**
  - **except all**

Null Values

- It is possible for tuples to have a null value, denoted by **null**, for some of their attributes
- The value **null** signifies an unknown value or that a value does not exist
- The result of any arithmetic expression involving **null** is **null**
  - Example: 5 + **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
```

- The predicate **is not null** succeeds if the value on which it is applied is not null

Null Values

- SQL treats as **unknown** the result of any comparison involving a null value
  - Example*: 5* < **null** or **null** <> **null** or **null** = **null**
- The predicate in a **where** clause can involve Boolean operations (**and**, **or**, **not**); thus, the definitions of the Boolean operations need to be extended to deal with the value **unknown**
  - **and** : *(true* **and** *unknown) = unknown,*
    (false **and** *unknown) = false,*
    (unknown **and** *unknown) = unknown*
  - **or:** (*unknown* **or** *true*) = *true*,
    (*unknown* **or** *false*) = *unknown*
    (*unknown* **or** *unknown) = unknown*
- Result of **where** clause predicate is treated as *false* if it evaluates to *unknown*

Three-Valued Logic

P	Q	$P \land Q$
T	T	T
T	F	F
F	T	F
F	F	F

P	Q	$P \lor Q$
T	T	T
T	F	T
F	T	T
F	F	F

P	Q	$P \land Q$
T	T	T
T	F	F
T	U	U
F	T	F
F	F	F
F	U	F
U	T	U
U	F	F
U	U	U

P	Q	$P \lor Q$
T	T	T
T	F	T
T	U	T
F	T	T
F	F	F
F	U	U
U	T	T
U	F	U
U	U	U

Examples

- Example: Find the names of all instructors with salary value **null**
  - **select** *name*
    from *instructor*
    where *salary* **is null**
- Example: Find the names of all instructors with salary value greater than 100000 is **unknown**
  - **select** *name*
    from *instructor*
    where *salary* > 100000 **is 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 Examples

- 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 2018 semester

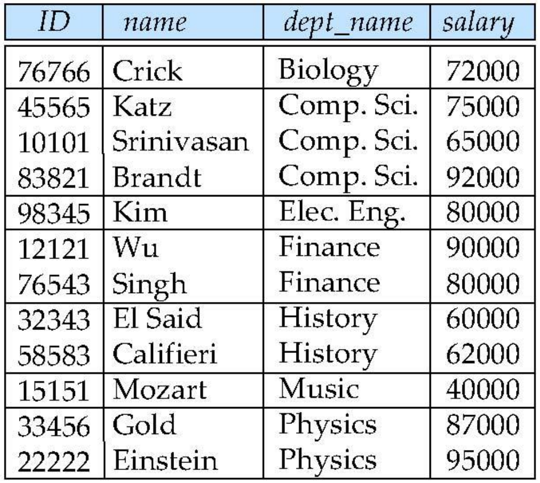
  -
    ```
    select count (distinct ID)
    from teaches
    where semester = 'Spring' and year = 2018;
    ```
- Find the number of tuples in the *course* relation

  -
    ```
    select count (*)
    from course;
    ```
- Find the minimum salary of instructors in the Computer Science department

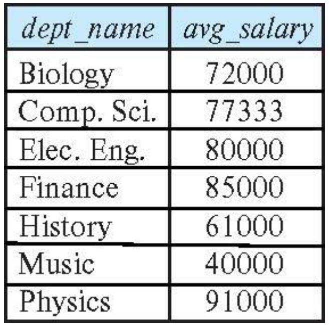
  -
    ```
    select min (salary)
    from instructor
    where dept_name= 'Comp. Sci.’;
    ```

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*;



ID	*name*	*dept_name*	*salary*
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



dept_name	*avg_salary*
Biology	72000
Comp. Sci.	77333
Elec. Eng.	80000
Finance	85000
History	61000
Music	40000
Physics	91000

- 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) as 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

Set Membership ("in") Clause

- SQL provides a mechanism for the nesting of subqueries. A **subquery** is a **select-from-where** expression that is nested within another query.
- Find courses offered in Fall 2017 and in Spring 2018

```
select distinct course_id
from section
where semester = 'Fall' and year= 2017 and
          course_id in (select course_id
                                    from section
                                    where semester = 'Spring' and year= 2018);
```

  - The subquery gives all courses taught in Spring 2018

- Find courses offered in Fall 2017 but not in Spring 2018

```
select distinct course_id
from section
where semester = 'Fall' and year= 2017 and
          course_id  not in (select course_id
                                          from section
                                          where semester = 'Spring' and year= 2018);
```

Set Membership

- Name all instructors whose name is neither “Mozart” nor Einstein”

```
select distinct name
from instructor
where name not in ('Mozart', 'Einstein')
```

- 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);
```

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 <comp> **some** *r* ⇔ ∃ *t* ∈ *r* such that (F <comp> *t*)
  Where <comp> can be: $<, \leq, >, =, \neq$

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

(read: 5 < some tuple in the relation)

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

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

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

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

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 <comp> **all** *r* $\Leftrightarrow \forall\, t \in r$ (F <comp> *t)*

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

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

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

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

($\neq$ **all**) $\equiv$ **not 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 2017 semester and in the Spring 2018 semester”

```
select course_id
from section as S
where semester = 'Fall' and year = 2017 and
          exists  (select *
                   from section as T
                   where semester = 'Spring' and year= 2018
                             and S.course_id = T.course_id);
```

- **Correlation name** – variable *S* in the outer query can be used in a subquery in the **where** clause
- **Correlated subquery** – a subquery that uses a correlation name from an outer 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 = Ø ⇔ $X \subseteq Y$
- The outer **select** takes each student and tests whether the set of all courses that the student has taken contains the set of all courses offered by the Biology department

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 2017

```
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 = 2017);
```

- Note that if a course were not offered in 2017, the subquery would return an empty results, and the unique predicate would evaluate to true on the empty set

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;
```

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

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

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

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

- Make each student in the Music department who has earned more than 144 credit hours an instructor in the Music department with a salary of $18,000

```
insert into instructor
    select ID, name, dept_name, 18000
    from   student
    where   dept_name = 'Music' and total_cred > 144;
```

Updates

- Give a 5% salary raise to all instructors

```
update instructor
   set salary = salary * 1.05
```

- Give a 5% salary raise to those instructors who earn less than 70000

```
update instructor
   set salary = salary * 1.05
   where salary < 70000;
```

- Give a 5% salary raise to instructors whose salary is less than average

```
update instructor
 set salary = salary * 1.05
 where salary <  (select avg (salary)
                    from instructor);
```

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

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
```