Chapter 3: Introduction to SQL

- 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, 2006, 2008, 2011
- 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
  - Also many minor differences in syntax

Data Definition Language

Allows the specification of not only a set of relations but also information about each relation, including:

- The schema for each relation.
- The domain of values associated with each attribute.
- 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 (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 *n* digits to the right of decimal point.
- **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 (e.g., for time and date)

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) **not null,**
  dept_name **varchar**(20),
  salary **numeric**(8,2))

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

Integrity Constraints in Create Table

- **not null**
- **primary key** $(A_1, ..., A_n)$
- **foreign key** $(A_m, ..., A_n)$ **references** r

Example: Declare *branch_name* as the primary key for *branch*

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) **primary key**,
  name **varchar**(20) not null,
  dept_name **varchar**(20),
  tot_cred **numeric**(3,0),
  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_idm semester, year),
  foreign key (*ID*) **references** *student,*
  foreign key (*course_id, sec_id, semester, year*) **references** *section*
  );

- *Note: when designing a schema, always identify primary keys, foreign keys, and not-null attributes.*

Drop and Alter Table Constructs

- **drop table**
- **alter table**
  - **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 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.

- *Note: when working with (most) DBMSs, put your SQL commands into files so you do not have to type them again.*

Basic Query Structure

- SQL is based on set and relational operations with certain modifications and enhancements
- A typical SQL query has the form:

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

  - A_i represents an attribute
  - R_i represents a relation
  - P is a predicate.
- This query is equivalent to the relational algebra expression.

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

- The result of an SQL query is a relation.

The select Clause

- The **select** clause list 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*

- In the relational algebra, the query would be:

$$\Pi_{name}(instructor)$$

- 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 names of all departments with instructor, and remove duplicates

  select distinct *dept_name*
  from *instructor*

- The keyword **all** specifies that duplicates 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*

- 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.

- Note: This is a generalized projection in Relational Algebra

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 with salary > 80000

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

- Comparison results can be combined using the logical connectives **and, or,** and **not.**
- Comparisons can be applied to results of arithmetic expressions, e.g., "**where** price * quantity > 1000"
- Note: some of the conditions act as join conditions, some as selections

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.

- Cartesian product not very useful directly, but useful combined with where-clause condition (selection operation in relational algebra).

Cartesian Product

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

teaches

ID	*course_id*	*sec_id*	*semester*	*year*
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

Inst.ID	*name*	*dept_name*	*salary*	*teaches.ID*	*course_id*	*sec_id*	*semester*	*year*
10101	Srinivasan	Physics	95000	10101	CS-101	1	Fall	2009
10101	Srinivasan	Physics	95000	10101	CS-315	1	Spring	2010
10101	Srinivasan	Physics	95000	10101	CS-347	1	Fall	2009
10101	Srinivasan	Physics	95000	10101	FIN-201	1	Spring	2010
10101	Srinivasan	Physics	95000	15151	MU-199	1	Spring	2010
10101	Srinivasan	Physics	95000	22222	PHY-101	1	Fall	2009
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
12121	Wu	Physics	95000	10101	CS-101	1	Fall	2009
12121	Wu	Physics	95000	10101	CS-315	1	Spring	2010
12121	Wu	Physics	95000	10101	CS-347	1	Fall	2009
12121	Wu	Physics	95000	10101	FIN-201	1	Spring	2010
12121	Wu	Physics	95000	15151	MU-199	1	Spring	2010
12121	Wu	Physics	95000	22222	PHY-101	1	Fall	2009
…	…	…	…	…	…	…	…	…
…	…	…	…	..	…	…	…	…

Joins

- For all instructors who have taught courses, find their names and the course ID of the courses they taught.

  select *name, course_id*
  from *instructor, teaches*
  where *instructor.ID = teaches.ID*

- Find the course ID, semester, year and title of each course offered by the Comp. Sci. department

  select *section.course_id, semester, year, title*
  from *section, course*
  where *section.course_id = course.course_id* **and**
  dept_name = 'Comp. Sci.'

- Note: you almost always want a join, not a Cartesian product. Also, joins are usually done along foreign keys.

Natural Join

- Natural join matches tuples with the same values for all common attributes, and retains only one copy of each common column
- **select** *
  from *instructor* **natural join** *teaches*;

ID	*name*	*dept_name*	*salary*	*course_id*	*sec_id*	*semester*	*year*
10101	Srinivasan	Comp. Sci.	65000	CS-101	1	Fall	2009
10101	Srinivasan	Comp. Sci.	65000	CS-315	1	Spring	2010
10101	Srinivasan	Comp. Sci.	65000	CS-347	1	Fall	2009
12121	Wu	Finance	90000	FIN-201	1	Spring	2010
15151	Mozart	Music	40000	MU-199	1	Spring	2010
22222	Einstein	Physics	95000	PHY-101	1	Fall	2009
32343	El Said	History	60000	HIS-351	1	Spring	2010
45565	Katz	Comp. Sci.	75000	CS-101	1	Spring	2010
45565	Katz	Comp. Sci.	75000	CS-319	1	Spring	2010
76766	Crick	Biology	72000	BIO-101	1	Summer	2009
76766	Crick	Biology	72000	BIO-301	1	Summer	2010

- Note: in general, join can be specified explicitly or in where clause.

Natural Join (Cont.)

- Danger in natural join: beware of unrelated attributes with same name which get equated incorrectly
- List the names of instructors along with the the titles of courses that they teach
- Incorrect version (equates course.dept_name with instructor.dept_name)
  - **select** *name*, *title*
    from *instructor* **natural join** *teaches* **natural join** *course*;
- Correct version
  - **select** *name*, *title*
    from *instructor* **natural join** *teaches*, *course*
    where *teaches.course_id*= *course.course_id*;
- Another correct version
  - **select** *name*, *title*
    from (*instructor* **natural join** *teaches*) **join** *course* **using**(*course_id*);

The Rename Operation

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

  old-name **as** *new-name*

- E.g.,
  - **select** *ID, name, salary/12* **as** *monthly_salary*
    from *instructor*

- 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* ≡ *instructor T*

- *Note: some systems require **as** to be omitted in **from** clause.*

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** '\'

- 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 if duplicates appear in the result.
- **Multiset** versions of some of the relational algebra operators – given multiset relations r_1 and r_2:

  1. $\boldsymbol{\sigma_\theta(r_1)}$**:** 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. $\boldsymbol{\Pi_A(r)}$**:** 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. $\boldsymbol{r_1 \times r_2}$**:** 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 $t_1.\ t_2$ 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 $\Pi_B(r_1)$ x r_2 would be

  $\{(a,2), (a,2), (a,3), (a,3), (a,3), (a,3)\}$

- SQL duplicate semantics:

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

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

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

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

- 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 + *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

- Any comparison with *null* returns *unknown*
  - Example*: 5 < null or null <> null or null = null*
- Three-valued logic using the truth value *unknown*:
  - OR: (*unknown* **or** *true*) = *true*,
    (*unknown* **or** *false*) = *unknown*
    (*unknown* **or** *unknown) = unknown*
  - AND: *(true* **and** *unknown) = unknown,*
    (false **and** *unknown) = false,*
    (unknown **and** *unknown) = unknown*
  - NOT*: (***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 (numerical) 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*)
    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

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*;

- Note: a very common mistake. But note that having ID in here also does not make sense if you think about it.
- But how about which instructor has highest salary in each department?

  select *dept_name*, *ID*, **max** (*salary*)
  from *instructor*
  group by *dept_name*;
  - Still not allowed!
  - And there could be several instructors making the maximum

Aggregation (Cont.)

- And ***never never*** do this!

  - /* erroneous query */
    select *ID*
    from *instructor*
    having max(salary)

- Does this output instructor making the maximum?
- No, completely nonsensical
- max(salary) is a number, say 20000.
- What does “having 20000” mean?
- having-expression has to evaluate to true of false

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

Aggregate Functions – Having Clause

- Full version of aggregation queries:
- select ... from ... where ... group by ... having ...
- E.g.,

select *dept_name*, **avg** (*salary*)
from *instructor* **join** *department*
where *budget > 100000*
group by *dept_name*
having avg (*salary*) > 42000;

Note: this is equivalent to RA expression

$$\Pi_{dept\_name,\ avs}\ (\ \sigma_{\ avs > 42000}\ (_{dept\_name}\ \mathcal{G}\ _{\mathbf{avg}(salary)\ as\ avs}\ (\sigma_{budget > 100000}\ (instructor \bowtie department\ )\ )\ )\ )$$

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

- Note: sum/count is not always same as avg, due to null values

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.
- A common use of subqueries is to perform tests for set membership, set comparisons, and set cardinality.

Example Query

- 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);
```

Example Query

- 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.

Usually should not do this:

- Output the names of all instructors who are in departments with budget > 100000

```
select name
from instructor
where dept_name in (select dept_name
                    from department
                    where budget > 100000);
```

- This is correct syntax, but a very complicated way to do a simple join
- Instead just do a join:

```
select name
from instructor join department
where budget > 100000;
```

Set Comparison

- 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’);

- Note: could also use min here (greater than the minimum)

Definition of Some Clause

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

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

(read: 5 < some tuple in the relation)

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

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

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

(= **some**) $\equiv$ **in**

However, ($\neq$ **some**) $\not\equiv$ **not in**

Example Query

- 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** $\{0, 5, 6\}$) = false

(5 < **all** $\{6, 10\}$) = true

(5 = **all** $\{4, 5\}$) = false

(5 ≠ **all** $\{4, 6\}$) = true (since 5 ≠ 4 and 5 ≠ 6)

(≠ **all**) ≡ **not in**
However, (= **all**) ≢ **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** $r \Leftrightarrow r = \emptyset$

Correlation Variables

- 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);
```

- **Correlated subquery**
- **Correlation name** or **correlation variable**

- Note: correlation can severely impact efficiency

Not Exists

- 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*));

- Note that $X - Y = \varnothing \Leftrightarrow X \subseteq Y$
- *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.

- 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);

Derived Relations

- 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 view 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 budget
from department, max_budget
where department.budget = max_budget.value;
```

- Note: often easy to output max, but hard to output who has the max

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;
```

Scalar Subquery

```
select dept_name,
          (select count(*)
             from instructor
           where department.dept_name = instructor.dept_name)
          as num_instructors
from department;
```

Modification of the Database – 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.

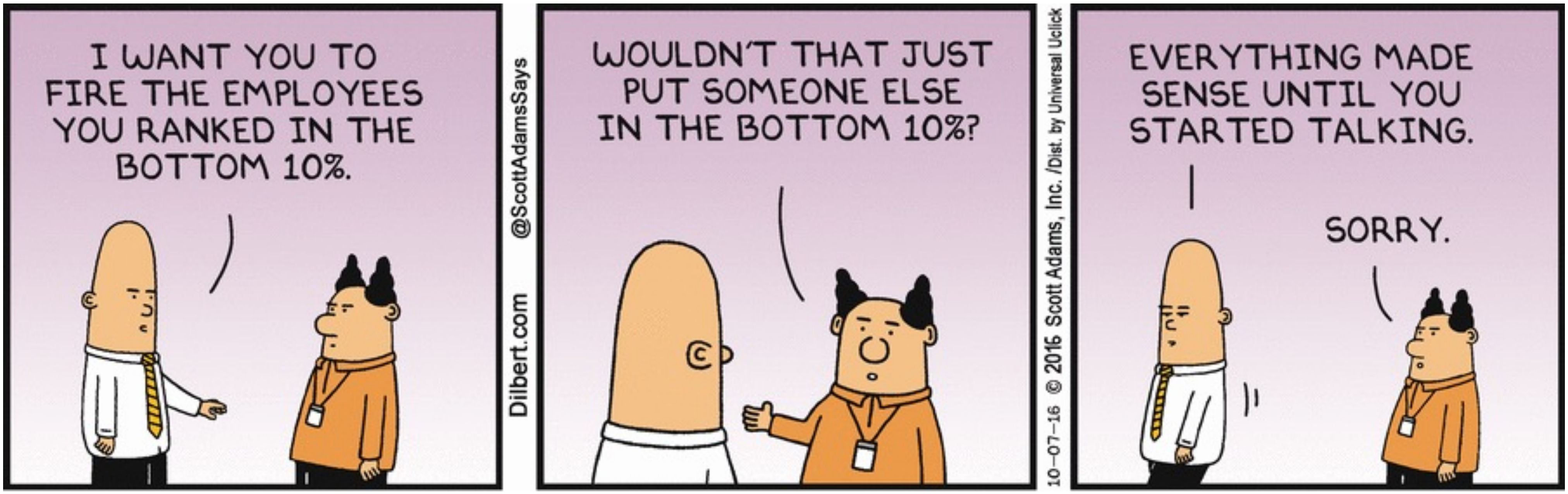
  delete from *instructor*
  where *dept name* **in** (**select** *dept name*
  from *department*
  where *building* = ’ Watson’);

Example Query

- 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 --> what would happen?
- 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)


I WANT YOU TO FIRE THE EMPLOYEES YOU RANKED IN THE BOTTOM 10%.
Dilbert.com @ScottAdamsSays
WOULDN'T THAT JUST PUT SOMEONE ELSE IN THE BOTTOM 10%?
10-07-16 © 2016 Scott Adams, Inc. /Dist. by Universal Uclick
EVERYTHING MADE SENSE UNTIL YOU STARTED TALKING.
SORRY.

Modification of the Database – 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*);

Modification of the Database – Insertion

- 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 *table*1 **select** * **from** *table*1
  would cause problems)

Modification of the Database – Updates

- Increase salaries of instructors whose salary is over $100,000 by 3%, and all others receive a 5% raise
  - 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 (why?)
  - 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_cred = ( select sum(credits)
                    from takes natural join course
                   where 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
```