Topic 8:

Structured Query Language (SQL)

Background (1 / 2)

- IBM's System R was released in 1978
  - – Its query language name: SEQUEL
    (Structured English QUEry Language)
  - – But trademarked by a British airplane company!
    (1982, Hawber Siddeley Dynamics Engineering Ltd.)
  - – After dropping the vowels: SQL
- IBM's current DB/2 was released in 1982; also used SQL
- SQL:
  - – A marriage of TRC to RA
  - – SQL = DML + DDL + DCL + QL + . . .

Background (2 / 2)

- SQL is no longer a proprietary language:
  - SQL is now an ANSI/ISO standard (ISO/IEC 9075)
  - Versions: 1989, ’92, ’99, ’03, ’06, ’08, ’11, ’16, . . .
- But no DBMS strictly follows any of them!
  - Example: Tuple IDs are non–standard
  - There is a basic subset you can count on

Relational Operators (1 / 5)

But first: SQL’s SELECT statement

- NOT identical to the select operator of Rel. Alg.!
- Most basic Form:

```
SELECT <attribute list>
FROM   <relation list>;
```

Example(s):

Relational Operators (2 / 5)

Now that we can perform π, we can answer our first standard query:

"What is the content of the Employee relation?"

Relational Operators (3 / 5)

Performing σ requires a new clause:

```
SELECT <attribute list>
FROM   <relation list>
```

Example(s):

What are the names and salaries of employees in department 5?

Relational Operators (4 / 5)

These are also all of the clauses that we need for $\bowtie$:

Example(s):

What are the names of the parts that can be supplied by individual suppliers in quantity > 200?

Relational Operators (5 / 5)

For completeness, our fourth standard query:

Example(s):

What are the names of the active suppliers of nuts?

```
SELECT sname
  FROM s, spj, p
 WHERE s.sno = spj.sno
   AND spj.pno = p.pno
   AND status > 0 AND pname = 'nut';
```

Column Aliases

You may give your result relations different attribute names:

Example(s):

```
select givenname as "First Name",
       surname as "Last Name",
       salary
  from employee
 where deptid = 5;
```


A Note about Duplicate Tuples

By default, SQL does not remove duplicate tuples from result relations. (Why not? It should, relations are sets!)

But SQL lets us override that behavior!

Example(s):

Ordering Result Tuples

We can sort tuples, too, with the ORDER BY clause.

Example(s):

Ascending Order:

Descending Order:

We can even do “phone book” sorting:


BASSETT Tom & Sandy Gregorak 205 Timberline Rd.......Hailey 788-3434
BATCHA FRANK MD 1450 Aviation Drive Ste 100........Ketchum 725-2021
BATEMAN A 3023 Warm Springs Rd........Ketchum 814-8700
BATES CORY MD 100 Hospital Drive Ste 201........Hailey 308-2448
BATES Craig PO Box 4338........Ketchum 726-3616
BATES Dale & Peggy 671-B 1st Ave N........Ketchum 726-6579
BATES Debbie 181 1st Ave N........Ketchum 788-8811
BATES Jeff & Nancy 540 Onyx Dr........Ketchum 727-7978
BATES Kim 3011 Warm Springs Rd........Ketchum 788-5950
BATES VICKY - INTERIOR MOTIVES PO Box 1820.........Sun Valley 928-7816
BATHEN Heather........726-0722
BATHUM Roy 235 Spur Ln........Ketchum See West Adam
BATMAN........726-7494
BATT Jeffrey & Camille........Ketchum 726-8896
BATTERSBY Patricia 116 Ritchie Dr........

Computed Columns

We can perform basic arithmetic with field values:

Example(s): Convert part weight from pounds to grams:

Tuple Aliases

We can assign relations temporary, alternate names.

Example(s):

Create all pairs of supplier names located within the same city:

Pattern Matching (1 / 2)

SQL allows us to search for values that match a particular pattern.

Form:

. . . **WHERE** *attribute* [not] **LIKE** '*pattern*'
[ESCAPE *escape character*]

Available wildcards:

- _ (underscore) matches any single character
- % matches 0 or more characters

Important: LIKE does not support regular expressions.

Pattern Matching (2 / 2)

Example(s):

Find the part names that have an 'o' as the second letter:

```
select pname
from   p
where  pname like '_o%';
```

To use wildcards as regular characters, ESCAPE them:

```
... where field like '%@%' escape '@';
```

Here, we match any string ending in a percent sign.

Regular Expressions (1 / 2)

Oracle offers REGEXP_LIKE for regular expressions.

Form (note that <*pattern*> and <*match*> are single–quoted):

. . . **WHERE REGEXP_LIKE** (<*source*>, '<*pattern*>', '<*match*>');

where:

<*source*> is an attribute name
<*pattern*> is a regular expression (see next slide)
<*match*> is a search modifier; e.g.:

`c` — case sensitive
`i` — case **in**sensitive
`x` — ignore whitespace
⋮

Regular Expressions (2 / 2)

REGEXP_LIKE options for <*pattern*> include:

.	—	(a period) match a single character
x*	—	match **x** 0 or more times
x+	—	match **x** 1 or more times
x?	—	match **x** 0 or 1 times
x|y	—	match **x** once or match **y** once
x{n,m}	—	match **x** at least **n** times, at most **m** times

Example(s):

Find the part names that have an 'o' as the second letter:

```
select pname
from   p
where  regexp_like( pname , '.o.*' , 'i' );
```


Set Operators (1 / 5)

Cartesian Product (×):

- Cartesian Product produces all pairs of tuples.
- Join produces all pairs of tuples that meet a condition.
- So . . . if we Join when the condition is always true . . .

Example(s): To form the Cartesian Product of S and P:

Set Operators (2 / 5)

Union ($\cup$):

- Form: select . . .
  union [all] (all $\equiv$ keep duplicates)
  select . . .
- Union compatibility still applies!

Example(s):

Set Operators (3 / 5)

Intersection ($\cap$) and Difference ($-$):

- The SQL keyword for set intersection is INTERSECT
- The SQL keyword for set difference is EXCEPT
  . . . except, Oracle uses MINUS
- Form: select . . .
  intersect/except
  select . . .

Example(s):

```
select city from s
EXCEPT                          <-- MINUS in Oracle
select city from p;
```

Set Operators (4 / 5)

The Return of . . . Division!

Version 1: Relational Algebra expression

Recall: $\alpha \div \beta = \pi_{\text{A-B}}(\alpha) - \pi_{\text{A-B}}((\pi_{\text{A-B}}(\alpha) \times \beta) - \alpha)$

And our sample division query:

> "Find the S#s of the suppliers who supply all parts
> of weight equal to 17."

Set Operators (5 / 5)

And so, $\alpha \div \beta = \pi_{\text{A-B}}(\alpha) - \pi_{\text{A-B}}((\pi_{\text{A-B}}(\alpha) \times \beta) - \alpha)$

becomes in SQL:

```
select sno from spj
except
select sno from
       ( select sno, pno
           from (select sno from spj) as t1,
                (select pno from p where weight=17) as t2
         except
         select sno, pno from spj
       ) as t3;
```

Aggregate Functions (1 / 3): Background

Idea: Let SQL compute basic statistical results for us

SQL provides aggregate functions for this purpose:

- **count([distinct] *attr*)** — counting entries in a relation
- **sum([distinct] *attr*)** — totaling values of *attr* in a relation
- **avg([distinct] *attr*)** — averaging values of *attr* in a relation
- **min(*attr*)** — smallest value of *attr* in a relation
- **max(*attr*)** — largest value of *attr* in a relation

Aggregate Functions (2 / 3)

Example(s): Variations on counting:

- `select count(city) from p;`
- `select count(distinct city) from p;`
- `select count(*) from p;`

Aggregate Functions (3 / 3)

Example(s):

If we have one of each part in a box, how much does the content weigh?

Which query will give the correct answer?

(a) `select sum(weight) from p;`
(b) `select sum(distinct weight) from p;`

Group By

Purpose: Apply aggregates to sub–groups of tuples

Example(s):

What are the average quantities in which suppliers are supplying parts?

Having

- Used in conjunction with 'group by'
- Purpose: Controls which group's aggregations are produced

Example(s):

Which suppliers are supplying parts in average quantity under 400, and what are those averages?

More on Nested Queries (1 / 4)

We've seen this idea before (e.g., the division query).

Another way to do nested queries is with the IN operator:

- IN tests set membership (form: tuple IN relation)
- We can negate the test (tuple NOT IN relation)
- Used in conjunction with a sub–query in a WHERE clause

Example(s):

Remember this query?

More on Nested Queries (2 / 4)

Example(s):

Idea: Create a set of parts available in quantity > 200,

and test each part from the DB against that set.

To create the P#s of the 'quantity > 200' parts:

```
select pno
from   spj
where  qty > 200;
```

And to produce the names of the parts in that set:

More on Nested Queries (3 / 4)

Notes:

- IN and NOT IN are only suitable for equality comparisons
- Other options include:
  -
  -
  -
  -

More on Nested Queries (4 / 4)

One more nested–query operator: EXISTS

Its purpose: Test if a relation holds at least one tuple

Example(s):

Another (awkward!) version of the qty > 200 query:

Division, Revisited (1 / 7)

Version 2: "Double $\neg\,\exists$"

Recall:

Find the S#s of the suppliers who supply all parts of weight 17.

Restated in logical English:

Find S#s such that $\forall$ parts of weight 17, $\exists$ suppliers that supply them all

Apply Double Negation and Generalized De Morgan's Laws:

$$\forall a\, \exists b\, f(a,b) \equiv \neg\, \exists a\, \neg\, \exists b\, f(a,b)$$

Returning to logical English:

Find S#s such that $\neg\,\exists$ parts of weight 17 for which $\neg\,\exists$ suppliers that supply them all

Division, Revisited (2 / 7)

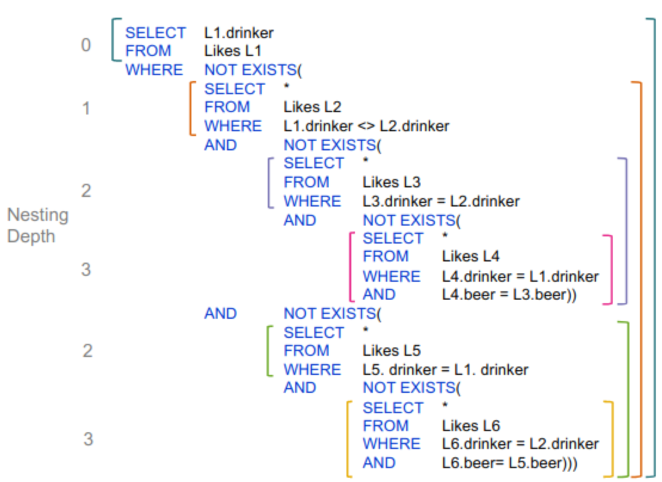
Find S#s such that ¬ ∃ parts of weight 17 for which ¬ ∃ suppliers that supply them all expressed in SQL:

```
select distinct sno
from   spj as global
where  not exists
     ( select pno
       from   p
       where  weight = 17 and not exists
            ( select *
              from   spj as local
              where  local.pno = p.pno
                and  local.sno = global.sno
            )
     )
```


Division, Revisited (3 / 7)

Aside: This query form is useful beyond division.

Example(s): Which drinkers like a unique set of beers?



Schema:

Likes(<u>drinker</u> , <u>beer</u>)

Source: Leventidis, A., et. al. “QueryVis: Logic–based Diagrams help Users Understand Complicated SQL Queries Faster.” Proceedings of the 2020 ACM SIGMOD International Conference on Management of Data, June 2020, pp. 2303–2318. https://doi.org/10.1145/3318464.3389767

Division, Revisited (4 / 7)

Version 3: Set Containment

Observation:

If B $\subseteq$ A, then B$-$A will be empty (or, $\neg\exists$(B–A))

Relevance:

If a supplier supplies a superset of the parts of weight 17, the supplier clearly supplies them all

A = The parts a supplier supplies

B = The parts of weight 17

Division, Revisited (5 / 7)

```
select distinct sno
from   spj as global
where  not exists (               --   not bkwd-E
    ( select pno
      from   p                    --   B
      where  weight = 17
    ) except (                    --   minus
      select p.pno
      from   p, spj               --   A
      where  p.pno = spj.pno
        and  spj.sno = global.sno
    )
)
```

Division, Revisited (6 / 7)

Version 4: Set Cardinality

Idea:

- For each supplier that supplies parts of weight 17, count those parts.
- If the total matches the number of weight 17 parts, that supplier supplies them all.

Division, Revisited (7 / 7)

```
select   distinct sno
from     spj, p
where    spj.pno = p.pno and weight = 17
group by sno
having   count(distinct p.pno) =
            ( select count (distinct pno)
              from   p
              where  weight = 17
            )
```

Outer Joins (1 / 5)

Regular ("inner") joins discard non-matching tuples.

Example(s): Name the employees who are supervising buildings.

M

Id	Name
1	Roy
2	Amy
3	Joy

N

Building	Supervisor
A	2
B	1
C	2
D	NULL

$M \bowtie_{id=supervisor} N$

Id	Name	Building	Supervisor
2	Amy	A	2
1	Roy	B	1
2	Amy	C	2

Outer Joins (2 / 5)

Now consider this slightly different query.

Example(s): Name all employees and the buildings they supervise.

Our desired answer:

M ? N

Id	Name	Building	Supervisor
1	Roy	B	1
2	Amy	A	2
2	Amy	C	2
3	Joy	NULL	NULL

But . . . how do we get this result from a join?

Outer Joins (3 / 5)

There are three varieties of outer join:

- Left Outer Join (⟕): Retains unmatched tuples from left relation
- Right Outer Join (⟖) Retains unmatched tuples from right relation
- Full Outer Join (⟗): Retains all unmatched tuples

Outer Joins (4 / 5)

The SQL outer join syntax:

select <*attribute list*>

from (<*relation*> **[left/right/full] outer join** <*relation*> **on** <*join condition*>)

where <*condition*> ;

Example(s): Name all employees and the buildings they supervise.

Outer Joins (5 / 5)

Outer join is not an fundamental operator.

We can fabricate outer join with UNION ALL.

Example(s): Name all employees and the buildings they supervise.

```
select id, name, building, supervisor
from   m, n
where  m.id = n.supervisor
```


SQL as DDL

First order of business: Creating a database!

The exact mechanism depends on the DBMS.

1. Postgres: `$ createdb <name>`
2. Oracle: `CREATE DATABASE <name>;`

Creating Relations (1 / 3)

Some sample attribute types:

- Integers: `integer`, `number(p)`
- Floats: `float`, `real`, `number(p,s)`
  - `p` is precision (total # digits), `s` is scale (# digits after decimal)
- Strings: `char(n)`, `varchar(n)`, `varchar2(n)`
- Others: `timestamp`, `blob`, `bfile`, . . .

Creating Relations (2 / 3)

To create a relation:

CREATE TABLE <*table name*> (

<*attribute name*> <*data type* > [NOT NULL],

. . .

[PRIMARY KEY (<*attribute*>)]

);

Creating Relations (3 / 3)

Example(s):

Creating the supplier (S) relation:

```
create table s (
    sno      varchar2(5),  -- the supplier ID number
    sname    varchar2(20), -- the supplier's name
    status   integer,      -- supplier status
    city     varchar2(15), -- location of supplier
    primary key (sno)
);
```


Creating Indices (1 / 3)

Form:

CREATE [UNIQUE] **INDEX** <*index name*>

ON <*table name*>

[USING <*access method*>]

(<*attribute name*> [, <*attribute name*> . . .]);

Creating Indices (2 / 3)

Example(s):

Create an index on `jno` in SPJ:

```
create index spj_j_index
on spj (jno);
```


Creating Indices (3 / 3)

Different DBMSes supply different kinds of indices; e.g.:

1. Oracle 11:
   - B–tree
     - Reverse Key (subtype of B–Tree, reverses bytes)
   - Function–based (to support queries using computations)
   - Bitmap (instead of storing lists of IDs)
   - Application Domain Indexes (user–defined)

2. Postgres 14:
   - B–tree
   - Hash (apparently linear hashing)
   - GiST (Generalized Search Tree) and SP–GiST
   - GIN (Generalized Inverted Index)
   - BRIN (Block Range Index)

Creating Views (1 / 2)

Remember the ANSI/SPARC External Layer?

Form:

CREATE VIEW <*view name*> [(<*attribute list*>)]

AS <*select statement*>;

Creating Views (2 / 2)

Example(s):

Create a view of supplier names and the IDs of the parts that they supply.

```
create view supplierpart ("Supplier Name", "Part #")
as   select distinct sname, pno
     from   s, spj
     where  s.sno = spj.sno;
```

Then, it is available for use:

```
select * from supplierpart;
```

View Updates (1 / 2)

Can users update the content of views? That is, can we convert a view update into updates of the view's base relations?

Example(s):

Consider a view that is a join of A and B:

A

<u>a</u>	b	c
x	2	b
y	1	a
z	1	b

B

<u>d</u>	a
6	y
1	y

$A \bowtie B$

<u>a</u>	b	c	<u>d</u>
y	1	a	6
y	1	a	1

View Updates (2 / 2)

Example(s): (continued!) Our desired result:

$A \bowtie B$

<u>a</u>	b	c	<u>d</u>
y	1	a	6
y	1	a	1
y	1	a	4
x	2	c	3

$\Rightarrow$

A

<u>a</u>	b	c
x	2	b
y	1	a
z	1	b
x	2	c

B

<u>d</u>	a
6	y
1	y
4	y
3	x

SQL as DML

The view update example raises a pertinent question:

How *do* we insert data into a relation?

With a DML operation, of course!

Inserting Tuples into a Relation

To insert a tuple into a relation:

INSERT INTO <*relation name*> [(<*column list*>)]
VALUES (<*expression list*>);

Example(s):

Bulk Loading a Database

Using INSERT INTO to populate tables is:

- Highly portable! (just create a script file), but
- Slow (especially you don't disable transations)

An alternative is a bulk–loading utility.

Example(s):

Updating Content of Tuples

To modify data in existing tuples:

UPDATE <*relation name*>

  SET <*attribute name*> = <*expression*> [, . . .]

  [FROM <*relation list*>]

  [WHERE <*condition*>];

Example(s):

Storing Query Results

Can we add query results (which are relations) to the DB?

Yes! Two options:

1. (Pretty universal) If you have an existing table:

   INSERT INTO <*relation name*>

   <*SELECT statement*>;

2. (Oracle) If you need to create the table, too:

   CREATE GLOBAL TEMPORARY TABLE <*relation name*>

   AS <*SELECT statement*>;

   (Table disappears at end of session.)

Deleting Tuples

Like updating, a condition is used to ID tuples for removal:

DELETE FROM <*relation name*>

WHERE <*condition*>;

Deleting Relations

To remove tables, indices, views, . . .

DROP { TABLE | INDEX | VIEW | DATABASE } <*name*>;

Wait! What About “SQL as DCL?”

We’ll cover that in Topic 14: Security.