Mapping ER to Rel to SQL

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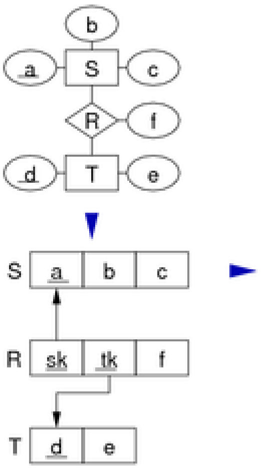


```
create table S (
    a integer,
    b float,
    c text,
    primary key(a)
);
create table T (
    d text,
    e date,
    primary key(d)
);
create table R (
    sk integer,
    tk text,
    f integer,
    primary key (sk,tk),
    foreign key(sk) references S(a),
    foreign key(tk) references T(d)
);
```

SQL

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SQL has several sub-languages:

- meta-data definition language (e.g. CREATE TABLE)
- meta-data update language (e.g. ALTER TABLE)
- data update language (e.g. INSERT, UPDATE, DELETE)
- query language (SQL) (e.g. SELECT)

Meta-data languages manage the *schema*.

Data languages manipulate (sets of) *tuples*.

Query languages are based on *relational algebra*.

SQL Syntax

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SQL definitions, queries and statements are composed of:

- *comments* ... `--` comments to end of line
- *identifiers* ... similar to regular programming languages
- *keywords* ... a large set (e.g. `CREATE`, `DROP`, `TABLE`)
- *data types* ... small set of basic types (e.g. `integer`, `date`)
- *operators* ... similar to regular programming languages
- *constants* ... similar to regular programming languages

Similar means "often the same, but not always" ...

... SQL Syntax

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How SQL syntax differs from regular programming languages ...

- single-quotes are used for strings
- double-quotes used for "non-standard" identifiers

Identifiers are case-insensitive (unless "double-quoted")

(`Staff` = `staff` = `STAFF` = `"staff"` ≠ `"Staff"` ≠ `"StAfF"`)

Variations in identifier syntax:

- Oracle also allows unquoted hash (#) and dollar ($) in identifiers.
- MySQL uses non-standard back-quote (`) instead of double-quote (").

... SQL Syntax

Identifiers denote:

- database objects such as tables, attributes, views, ...
- meta-objects such as types, functions, constraints, ...

Naming conventions that I (try to) use in this course:

- relation names: e.g. `Branches`, `Students`, ...
- attribute names: e.g. `name`, `code`, `firstName`, ...
- foreign keys: named after either or both of
  - table being referenced e.g. `staff`, ...
  - relationship being modelled e.g. `teaches`, ...

We initially write SQL keywords in all upper-case in slides.

Types/Constants in SQL

Numeric types: `INTEGER`, `REAL`, `NUMERIC(`*w*`,`*d*`)`

```
10    -1    3.14159    2e-5    6.022e23
```

two spaces

String types: `CHAR(`*n*`)`, `VARCHAR(`*n*`)`, `TEXT`

```
'John'   'some text'   '!%#%!$'   'O''Brien'
'"'   '[A-Z]{4}\d{4}'   'a VeRy! LoNg String'
```

PostgreSQL provides extended strings containing \ escapes, e.g.

```
E'\n'   E'O\'Brien'   E'[A-Z]{4}\\d{4}'   E'John'
```

Type-casting via *Expr*`::`*Type* (e.g. `'10'::integer`)

... Types/Constants in SQL

Logical type: `BOOLEAN`, `TRUE` and `FALSE` (or `true` and `false`)

PostgreSQL also allows `'t'`, `'true'`, `'yes'`, `'f'`, `'false'`, `'no'`

Time-related types: `DATE`, `TIME`, `TIMESTAMP`, `INTERVAL`

```
'2008-04-13'   '13:30:15'   '2004-10-19 10:23:54'
'Wed Dec 17 07:37:16 1997 PST'
'10 minutes'   '5 days, 6 hours, 15 seconds'
```

Subtraction of timestamps yields an interval, e.g.

```
now()::TIMESTAMP - birthdate::TIMESTAMP
```

PostgreSQL also has a range of non-standard types, e.g.

- geometric (point/line/...), currency, IP addresses, XML, objectIDs, ...
- non-standard types typically have string literals (`'...'`) (except OIDs)

... Types/Constants in SQL

Users can define their own types in several ways:

```
-- domains: constrained version of existing type

CREATE DOMAIN Name AS Type CHECK ( Constraint )

-- tuple types: defined for each table

CREATE TYPE Name AS ( AttrName AttrType, ... )

-- enumerated type: specify elements and ordering

CREATE TYPE Name AS ENUM ( 'Label', ... )
```

Exercise: Defining domains

Give suitable domain definitions for the following:

- positive integers
- a person's age
- a UNSW course code
- a UNSW student/staff ID
- colours (as used in HTML/CSS)
- pairs of integers *(x,y)*
- standard UNSW grades (FL,PS,CR,DN,HD)

[Solution]

Exercise: Enumerated types

How are the following different?

```
CREATE DOMAIN SizeValues1 AS
   text CHECK (value in ('small','medium','large'));
```

large < medium < small

```
CREATE TYPE SizeValues2 AS
   ENUM ('small','medium','large');
```

enum is from 0   *small < medium < large*

Tuple and Set Literals

Tuple and set constants are both written as:

(val_1, val_2, val_3, ...)

The correct interpretation is worked out from the context.

Examples:

```
INSERT INTO Student(studeID, name, degree)
   VALUES (2177364, 'Jack Smith', 'BSc')
          -- tuple literal

CONSTRAINT CHECK gender IN ('male','female')
                           -- set literal
```

SQL Operators

Comparison operators are defined on all types:

not equal to

`<`   `>`   `<=`   `>=`   `=`   `<>`

In PostgreSQL, `!=` is a synonym for `<>` (but there's no ==)

Boolean operators `AND`, `OR`, `NOT` are also available

Note `AND`,`OR` are not "short-circuit" in the same way as C's `&&`,`||`

Most data types also have type-specific operations available

See PostgreSQL Documentation Chapter 8/9 for data types and operators

---

... SQL Operators

String comparison: *compare the string in dictionary order*

- *str_1 < str_2* ... compare using dictionary order
- *str* `LIKE` *pattern* ... matches string to pattern

Pattern-matching uses SQL-specific pattern expressions:

`%` matches anything (cf. regexp `.*`)

`_` matches any single char (cf. regexp `.`)

you can use a 'like' pattern to check a pile of tihngs

... SQL Operators

Examples (using SQL92 pattern matching):

`name LIKE 'Ja%'`	`name` begins with 'Ja'	
`name LIKE '_i%'`	`name` has 'i' as 2nd letter	
`name LIKE '%o%o%'`	`name` contains two 'o's	*???????o???????o????*
`name LIKE '%ith'`	`name` ends with 'ith'	
`name LIKE 'John'`	`name` equals 'John'	*This one is bad, because it is 100 times slower than '='*

mail_address like '%@%.%'

PostgreSQL also supports case-insensitive match: `ILIKE`

... SQL Operators

Many DBMSs also provide *regexp*-based pattern matching
(*regexp* = *regular expression*; the POSIX regexp library is widely available)

PostgreSQL uses `~` and `!~` operators for this:

`Attr ~ 'RegExp'`   or   *`Attr !~ 'RegExp'`*

Also provides case-insensitive matching (makes some regexps shorter)

`Attr ~* 'RegExp'`   or   *`Attr !~* 'RegExp'`*

PostgreSQL also provides full-text searching (see Chapter 12)

... SQL Operators

Examples (using POSIX regular expressions):

`name ~ '^Ja'`	`name` begins with 'Ja'
`name ~ '^.i'`	`name` has 'i' as 2nd letter
`name ~ '.*o.*o.*'`	`name` contains two 'o's
`name ~ 'ith$'`	`name` ends with 'ith'
`name ~ 'John'`	`name` contains 'John'

'^' means the beginning of the line

'.' means one character

'.*' means many character

... SQL Operators

String manipulation:

- *str*$_1$ `||` *str*$_2$ ... return concatenation of *str*$_1$ and *str*$_2$
- `lower(`*str*`)` ... return lower-case version of *str*
- `substring(`*str,start,count*`)` ... extract substring from *str*

Etc. etc. ... consult your local SQL Manual (e.g. PostgreSQL Sec 9.4)

Note that above operations are null-preserving (strict):

- if any operand is `NULL`, result is `NULL`
- beware of `(a||'  '||b)` ... `NULL` if either of `a` or `b` is `NULL`

... SQL Operators

Arithmetic operations:

```
+  -  *  /  abs  ceil  floor  power  sqrt  sin  etc.
```

Aggregations "summarize" a column of numbers in a relation:

- `count(`*attr*`)` ... number of rows in *attr* column
- `sum(`*attr*`)` ... sum of values for *attr*
- `avg(`*attr*`)` ... mean of values for *attr*
- `min/max(`*attr*`)` ... min/max of values for *attr*

Note: `count` applies to columns of non-numbers as well.

The NULL Value

Expressions containing `NULL` generally yield `NULL`.

However, boolean expressions use three-valued logic:

a	*b*	*a* AND *b*	*a* OR *b*
TRUE	TRUE	TRUE	TRUE
TRUE	FALSE	FALSE	TRUE
TRUE	NULL	NULL	TRUE
FALSE	FALSE	FALSE	FALSE

Treat it as unknown, it is easier for you to remember the truth table

FALSE	NULL	FALSE	NULL
NULL	NULL	NULL	NULL

... The `NULL` Value

Important consequence of `NULL` behaviour ...

These expressions do not work as (might be) expected:

`x = NULL`   `x <> NULL`

Both return `NULL` regardless of the value of *x*

Can only test for `NULL` using:

`x IS NULL`   `x IS NOT NULL`

Conditional Expressions

Other ways that SQL provides for dealing with `NULL`:

`coalesce(`val_1`,`val_2`,`...val_n`)`

- returns first non-null value val_i
- useful for providing a "displayable" value for nulls

E.g. `select coalesce(mark,'??') from Marks ...`

`nullif(`val_1`,`val_2`)`

- returns `NULL` if val_1 is equal to val_2 *This will return the first un-null value*
- can be used to implement an "inverse" to `coalesce`

E.g. `nullif(mark,'??')`

... Conditional Expressions

SQL also provides a generalised conditional expression:

```
CASE
   WHEN test1 THEN result1
   WHEN test2 THEN result2
   ...
   ELSE resultn
END
```

E.g. `case when mark>=85 then 'HD' ... else '??' end`

Tests that yield `NULL` are treated as `FALSE`

If no `ELSE`, and all tests fail, `CASE` yields `NULL`

SQL: Schemas

SQL Data Definition

Relations (tables) are declared using:

```
CREATE TABLE RelName (
    attribute1    domain1    constraints1,
    attribute2    domain2    constraints2,
    ...
    table-level constraints, ...
);
```

where *constraints* can include details about primary keys, foreign keys, default values, and constraints on attribute values.

Defines table schema *and* creates empty instance of table.

Tables are removed via `DROP TABLE` *RelName*;

... SQL Data Definition

Example table definition:

```
create table Students (
    id          integer, -- e.g. 3123456
    familyName  text,    -- e.g. 'Smith'
    givenName   text,    -- e.g. 'John'
    birthDate   date,    -- e.g. '1-Mar-1984'
    degree      integer, -- e.g. 3648
    wam         float,   -- e.g. 84.75 (derived)
    primary key (id),
    foreign key (degree) references Degrees(id)
);
```

Primary key ⇒ `unique not null`

Primary Keys

If we want to define a numeric primary key, e.g.

```
CREATE TABLE R ( id INTEGER PRIMARY KEY, ... );
```

we still have the problem of generating unique values.

Most DBMSs provide a mechanism to

- generate a sequence of unique values
- ensure that two tuples don't get assigned the same value

PostgreSQL's version:

```
CREATE TABLE R ( id SERIAL PRIMARY KEY, ... );
INSERT INTO R VALUES ( DEFAULT, ...);
```

Referential Integrity

Declaring foreign keys assures **referential integrity**.

E.g. `Account.branch text references Branch(name)`

Every `Account` tuple must contain an existing `Branch` name.

If we want to delete a tuple from `Branch`, and there are tuples in `Account` that refer to it, we could ...

- **reject** the deletion (PostgreSQL default behaviour)
- **set-NULL** the foreign key attributes in `Account` records
- **cascade** the deletion and remove `Account` records

Exercise: Data Insertion

Consider the following schema:

```
create table R (
   id integer primary key,
   s  char(1) references S(id)
);
create table S (
   id char(1) primary key,
   r  integer references R(id)
);
```

make a froeigne key deferrable

Devise a method to:

- load the schema
- `INSERT` data into the tables

Advanced: what if both foreign keys were `NOT NULL`.
[Solution]

Other Attribute Properties

Example (the red constraint is invalid):

```
CREATE TABLE Example (
   gender char(1) CHECK (gender IN ('M','F')),
   Xval   integer NOT NULL,
   Yval   integer CONSTRAINT isPos CHECK (Yval > 0),
   Zval   real    DEFAULT 100.0,
   CONSTRAINT     XgtY CHECK (Xval > Yval),
   CONSTRAINT     Zcondition CHECK
                  (Zval >
                    (SELECT MAX(price) FROM Sells)
                  )
);
```

SQL: Queries

SQL Query Language

SQL provides powerful, high-level manipulation of data.

However, SQL is *not* a complete programming language.

Applications typically embed SQL into programming languages:

- Java and the JDBC API
- PHP/Perl/Tcl and their various DBMS bindings
- RDBMS-specific programming languages
  (e.g. Oracle's PL/SQL, PostgreSQL's PLpgSQL)
- C-level library interfaces to DBMS engine
  (e.g. Oracle's OCI, PostgreSQL's libpq)

... SQL Query Language

An SQL *query* consists of a sequence of clauses:

```
SELECT   projectionList
FROM     relations/joins
WHERE    condition
GROUP BY groupingAttributes
HAVING   groupCondition
```

`FROM`, `WHERE`, `GROUP BY`, `HAVING` clauses are optional.

Result of query: a relation, typically displayed as a table.

Result could be just one tuple with one attribute (i.e. one value) or even empty

---

... SQL Query Language

Schema:

- *Students(id, name, ...)*
- *Enrolments(student, course, mark, grade)*

Example SQL query:

```
SELECT   s.id, s.name, avg(e.mark) as avgMark
FROM     Students s, Enrolments e
WHERE    s.id = e.student
GROUP BY s.id, s.name
-- or --
SELECT   s.id, s.name, avg(e.mark) as avgMark
FROM     Students s
           JOIN Enrolments e on (s.id = e.student)
GROUP BY s.id, s.name
```

... SQL Query Language

How the example query is computed:

- produce all pairs of *Students*,*Enrolments* tuples
  which satisfy condition *(Students.id = Enrolments.student)*
- each tuple has *(id,name,...,student,course,mark,grade)*
- form groups of tuples with same *(id,name)* values
- for each group, compute average mark
- form result tuples *(id,name,avgMark)*

Problem-solving in SQL

Request: description of required information from database.

Pre-req: *know your schema*

Look for keywords in request to identify required data :

- tell me the names of all students...
- how many students failed ...
- what is the highest mark in ...
- which courses are ... (course codes?)

... Problem-solving in SQL

Developing SQL queries ...

- relate required data to *attributes* in schema
- identify which *tables* contain these attributes
- combine data from relevant tables (*FROM*, *join*)
- specify conditions to select relevant data (*WHERE*)
- [optional] define grouping attributes (*GROUP BY*)
- develop expressions to compute output values (*SELECT*)

Views

A *view* associates a name with a query:

- **CREATE VIEW** *viewName* [**(** *attributes* **)**] **AS** *Query*

Each time the view is invoked (in a `FROM` clause):

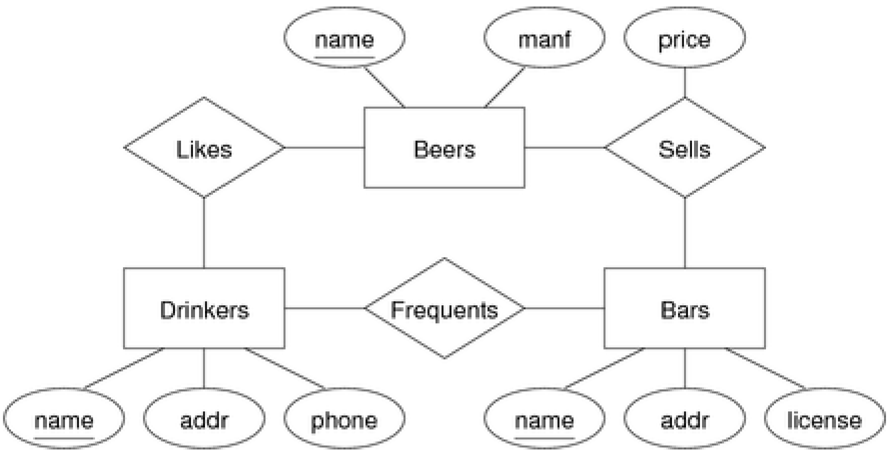
- the *Query* is evaluated, yielding a set of tuples
- the set of tuples is used as the value of the view

A view can be treated as a "virtual table".

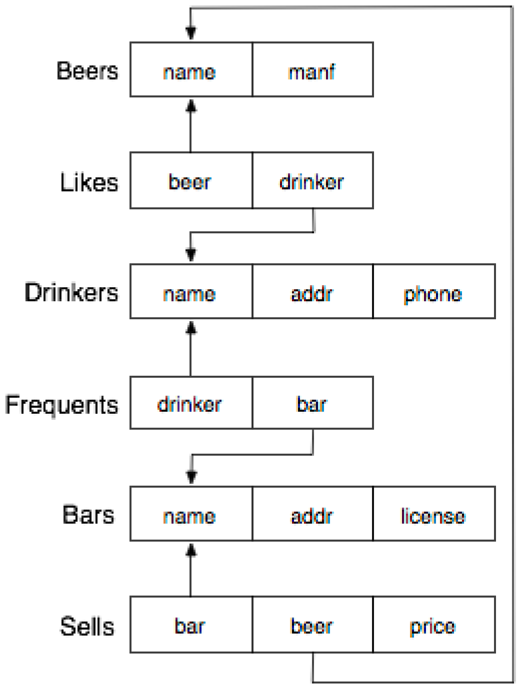
Views are useful for "packaging" a complex query to use in other queries.

Exercise: Queries on Beer Database

ER design for Beer database:



... Exercise: Queries on Beer Database



Answer these queries on the Beer database:

1. What beers are made by Toohey's?
2. Show beers with headings "Beer", "Brewer".
3. Find the brewers whose beers John likes.
4. Find pairs of beers by the same manufacturer.
5. Find beers that are the only one by their brewer.
6. Find the beers sold at bars where John drinks.
7. How many different beers are there?
8. How many different brewers are there?

You can use distinct to remove redundant things.

distinct first sort the table and the remove redundant things

[Solution]

Produced: 9 Aug 2016