122COM: Databases

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2017

Overview

SQL

Database *(noun)* - a collection of information that is organized so that it can easily be accessed, managed, and updated.

- Pronounced S-Q-L or Sequel.
  - Structured Query Language.
- Used to query relational databases.
- Theoretically it doesn't matter what underlying database is.
  - MS SQL Server, Oracle, PostgreSQL, MySQL, SQLite.
  - In reality lots of minor variations.

Relational Databases

Built around tables.

- Can be imagined like a spreadsheet.

Row/record →

id	forename	surname	job
0	Malcolm	Reynolds	Captain
4	Zoe	Washburne	Co-captain
11	Hoban	Washburne	Pilot
23	Kaywinnet	Frye	Mechanic

↑ Column/attribute

C

Many types of query.

- SELECT - Get information from the database.
- INSERT - Add information to the database.
- DELETE - Remove information.

Also used for database administration.

- CREATE - Create a whole new table/schema/function.
- ALTER - Modify a table/schema/function.
- DROP - Delete a whole table/schema/function.

SELECT

Used to retrieve information from the database.

id	forename	surname	job
0	Malcolm	Reynolds	Captain
4	Zoe	Washburne	Co-captain
11	Hoban	Washburne	Pilot
23	Kaywinnet	Frye	Mechanic

```
SELECT * FROM staff;
```

`*` means everything.

#	id	forename	surname	job
1	0	Malcolm	Reynolds	Captain
2	4	Zoe	Washburne	Co-captain
3	11	Hoban	Washburne	Pilot
4	23	Kaywinnet	Frye	Mechanic

SELECT

Used to retrieve information from the database.

id	forename	surname	job
0	Malcolm	Reynolds	Captain
4	Zoe	Washburne	Co-captain
11	Hoban	Washburne	Pilot
23	Kaywinnet	Frye	Mechanic

```
SELECT * FROM staff WHERE surname = "Washburne";
```

Only return the records `WHERE` something is true.

#	id	forename	surname	job
1	4	Zoe	Washburne	Co-captain
2	11	Hoban	Washburne	Pilot

count()

What if we want to now how many records there are?

- count() function.
- More efficient.
  - Minimum amount of data.

id	forename	surname	job
0	Malcolm	Reynolds	Captain
4	Zoe	Washburne	Co-captain
11	Hoban	Washburne	Pilot
23	Kaywinnet	Frye	Mechanic

```
SELECT count(*) FROM staff;
```

#	count(*)
1	4

INSERT

Used to add information to the database.

id	forename	surname	job
0	Malcolm	Reynolds	Captain
4	Zoe	Washburne	Co-captain
11	Hoban	Washburne	Pilot
23	Kaywinnet	Frye	Mechanic

```
INSERT INTO staff VALUES (42, 'Simon', 'Tam', 'Doctor');
```

id	forename	surname	job
0	Malcolm	Reynolds	Captain
4	Zoe	Washburne	Co-captain
11	Hoban	Washburne	Pilot
23	Kaywinnet	Frye	Mechanic
42	Simon	Tam	Doctor

INSERT again

Don't have to supply values for all the columns.

- Depends on the table design.

```
INSERT INTO staff (forename, id, surname)
      VALUES ('River', 43, 'Tam');
```

id	forename	surname	job
0	Malcolm	Reynolds	Captain
4	Zoe	Washburne	Co-captain
11	Hoban	Washburne	Pilot
23	Kaywinnet	Frye	Mechanic
42	Simon	Tam	Doctor
43	River	Tam	

Databases

Why use databases at all?
Why not just use dictionaries and lists or similar?

Databases...

- Have structure.
  - Easy to organise the data.
- Scale.
  - Can handle a LOT of data.
- Multi-user.
  - Can have lots of people working on the same data.
- Fault tolerant.
  - Can recover if things go wrong.

SQLite

Using SQLite3 in labs.

- Not a fully featured database.
  - But has all the basic features.
  - SQL.
- Good for small/non-urgent databases.
  - $\leq$ gigabytes of data.
- Efficient
  - Don't need to waste resources on a 'real' database.
- Convenient.
  - Don't need to install, configure, manage a 'real' database.
  - Portable, 1 file.
- No network.
  - Single user only.

Python

How to use SQL queries in Python?

```
import sqlite3 as sql                                  # sqlite module

con = sql.connect( 'firefly.sqlite' )                  # open database
cur = con.cursor()

cur.execute( '''SELECT * FROM staff;''' )              # run query
for row in cur:                                          # loop over results
    print( row )

con.close()                                            # close database
```

lec_select.py

```
(0, 'Malcolm', 'Reynolds', 'Captain')
(4, 'Zoe', 'Washburne', 'Co-captain')
(11, 'Hoban', 'Washburne', 'Pilot')
(23, 'Kaywinnet', 'Frye', 'Mechanic')
```

How to use SQL queries in C++?

```cpp
#include "libsqlite.hpp"                        // sqlite library

int main()
{
    sqlite::sqlite db( "firefly.sqlite" );     // open database

    auto cur = db.get_statement();              // create query
    cur->set_sql( "SELECT * FROM staff;" );
    cur->prepare();                              // run query

    while( cur->step() )                       // loop over results
        cout << cur->get_int(0) << " " << cur->get_text(1) << endl;
}
```

lec_select.cpp

```
0 Malcolm
4 Zoe
11 Hoban
23 Kaywinnet
```

Break

Static queries

So far looked at static queries.

- Same query is run every time.
- Real power is in dynamic queries.
  - Code creates changes the SQL to ask new questions.

Dynamic queries


```
import sqlite3 as sql

con = sql.connect('firefly.sqlite')
cur = con.cursor()

question = input('Who is the...')

cur.execute('''SELECT forename, surname FROM staff
               WHERE job = ?;''', (question,))

for row in cur:
    print('%s %s' % row)
```

lec_dynamic.py

```
Who is the...Captain
Malcolm Reynolds
```

Dynamic queries C++

Using sqlitepp.

- 3rd party wrapper around default SQLite3 API.
- Simplified use.

```
sqlite::sqlite db( "firefly.sqlite" );

string question;
cout « "Who is the...";
cin » question;

auto s = db.get_statement();
s->set_sql( "SELECT forename, surname FROM staff "
            "WHERE job = ?;" );
s->prepare();
s->bind( 1, question );

while( s->step() )
{
    string forename = s->get_text(0);
    string surname = s->get_text(1);
    cout « forename « " " « surname « endl;
}
```

lec_dynamic.cpp

Bad dynamic queries

Dynamic queries should **ALWAYS** use placeholders (i.e. ?).

```
cur.execute('''SELECT forename, surname FROM staff
               WHERE job = ?;''', (question,))
```

Dynamic queries must **NEVER** be created by manipulating strings.

```
cur.execute('''SELECT forename, surname FROM staff
               WHERE job = "%s";''' % question )
cur.execute('''SELECT forename, surname FROM staff
               WHERE job = "{}";'''.format( question) )
```

- User could input anything, e.g. SQL commands!.
  - `Captain"; DROP TABLE staff; -`
- Sanitise your inputs.
- Always use placeholders.
  - No exceptions.
  - NO EXCEPTIONS!

SQL injection

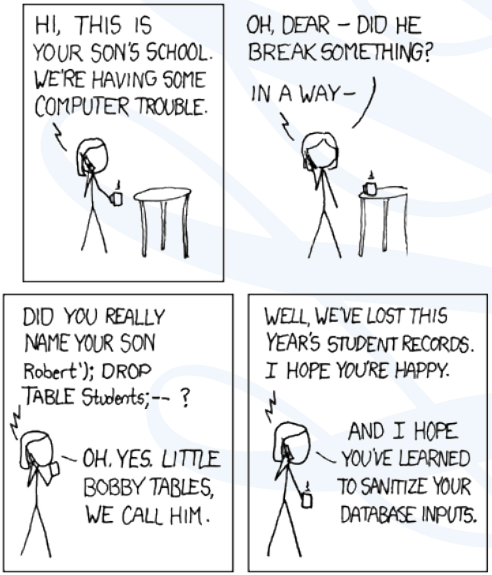
A

Around since at least 1998.

Notable SQL injection attacks.

- 2017 Equifax - 143,000,000 US consumers potentially impacted.
  - Or to put it another way, half of America.
- 2015 TalkTalk - 160,000 customers' details.
- 2014 Hold security - found 420,000 vulnerable websites.
- 2011 MySql - mysql.com compromised.
- 2008 Heartland Payment - 134,000,000 credit cards.

Many, many more.



https://xkcd.com/327/

SQL injection

Injection attacks are **STILL** No. 1 on Open Web Application Security Project (OWASP) Top 10 list.

- How is this still a thing?
- Do **NOT** write code that is vulnerable to this.
  - Do **NOT** write code that execute user input directly.
  - Just use placeholders! Problem solved.
- SQL injection is a critical bug and I **WILL** mark down code that is vulnerable.

Recap

- SQL used to query databases.
  - Databases are...
    - fault tolerant.
    - multi user.
    - scalable.
- Always use place holders in dynamic queries.
  - Say no to SQL injection!

Why do I care?

- Everyone
  - Structured Query Language (SQL) is widely used, most in demand language[1].
  - Should be aware of and able to defend against SQL injection.
  - Experience in using 3rd party libraries/modules in software.
- Computing - SQL is a vital for much of the web. Heard of LAMP servers?, the M is for MySQL.
- Ethical Hackers - need to understand SQL injection.
- ITB - SQL is widely used in business applications, especially for generating reports.
- Games Tech & MC- SQL is used in games, i.e. for save games.

[1] According to Indeed.com

Further reading

- Introduction to SQL - `http://www.w3schools.com/sql/sql_intro.asp`
- SQL injection hall of shame - `http://codecurmudgeon.com/wp/sql-injection-hall-of-shame/`
- Efficient inserting - the `executemany()` method.

The End