CS 2340 Objects and Design
SQL

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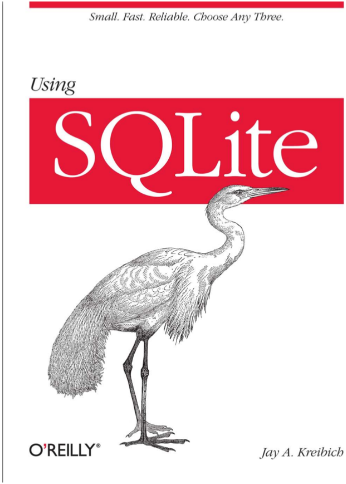

[1]

[1] The material in this lecture is taken from, Using SQLite3, by Jay Kreibich, whcih is an excellent introduction to databases in general and SQLite in particular.

The SQL Language

Relational databases and the SQL langauge are inexorably tied.

- Issuing SQL commands is the way you create and manipulate data in relational databases.
- Proficiency in using relational databases means proficiency in SQL.

We'll learn the basics of SQL today, using SQLite:

- creating tables (`create table`),
- inserting new data into tables (`insert`),
- updating existing data in tables (`update`),
- deleting data from tables (`delete`), and
- querying tables (`select`).

Most of these commands are quite simple. `select` is like a language unto itself, so we'll spend most of our time with `select`.

create table

The basic syntax of the create table command is

`CREATE TABLE table_name (`
  column_name column_type [*column_constraints...*],
`[...] );`

Here's an example

```
create table if not exists author (
  author_id integer primary key autoincrement,
  first_name text not null check(first_name != ''),
  last_name text not null check(last_name != '')
);
```

The names of the fields, or *columns* of this table are author_id, first_name, and last_name. Now we'll learn what the rest of the column definitions mean.

Column Types

- Attributes have data types, a.k.a. domains
- SQLite is manifest-typed, meaning it can store any type of value in any column, but most RDBMSes are statically typed
- SQLite has typed storage classes and type affinities for columns (a suggestion to convert data to specified type)
- SQLite supports the following type affinities:
    - text - NULL, text, or BLOB
    - numeric - integers, floats, NULLs, and BLOBs
    - integer - like numeric, but floats with no fractional part are converted to integers
    - float - like numeric, but integers are converted to floats
    - none - no preference over storage class

Column Constraints

```
create table if not exists author (
  author_id integer primary key autoincrement,
  first_name text not null check(first_name != ''),
  last_name text not null check(last_name != '')
);
```

- `primary key` means that the column uniquely identifies each record, or *row* in the table. Note that *integer* primary key fields are assigned automatically so that you don't have to assign them manually when inserting new rows into the table (we'll learn about composite keys later)
- `autoincrement` means that each new automatically assigned primary key will be greater than any existing primary key
- `not null` means the column cannot contain any `null` values
- `check(first_name != ”)` means that you cannot insert an empty string into the field

Foreign Keys

One-to-one or one-to-many relationship can be established between tables usign *foreign keys*, Consider the following tables.

```
create table if not exists venue (
  venue_id integer primary key,
  booktitle text not null not null check(booktitle != ''),
  month text not null check(month != ''),
  year integer not null
);
create table if not exists pub (
  pub_id integer primary key,
  title text not null check(title != ''),
  venue_id integer not null references venue(venue_id)
);
```

A single venue can have many publications.

- The `references venue(venue_id)` constraint on the `venue_id` field in `pub` table makes `venue_id` a foreign key which references the primary key, `venue_id`, of the `venue` table

Many-to-Many Relationships

A single author can write many publications, and a single publication can have many authors. This is a many-to-many relationship, which is modeled in relational databases with a *link table* or *bridge table*. Consider:

```
create table if not exists author_pub (
  author_id integer not null references author(author_id),
  pub_id integer not null references pub(pub_id),
  author_position integer not null, -- first author, second, etc?

  primary key (author_id, pub_id)
);
```

`author_pub` links the `author` and `pub` tables

- `author_id` and `pub_id` are both foreign keys
- Together, `author_id` and `pub_id` comprise a composite key for the table, which is created with the table level constraint `primary key (author_id, pub_id)`

Inserting Data

Inserting new rows into a table is done with the `insert` command:

`insert into` *table_name* [(*column_name* [, ...])]
`values` (*new_value* [, ...]);

Can insert data without specifying column names, which means you must include all values, which are resolved by position in the table schema:

```
insert into author values (1, "Jenny", "McCarthy");
```

Or you can specify column names, which means the values are resolved by position relative to the list of column names:

```
insert into author (first_name, second_name) values ("Jenny",
    "McCarthy");
```

The second version is easier to maintain and allows auto-generated fields (like the primary key) to do their job

Updating Data

You update existing rows of a table using the `update` command:

`update` *table_name* `set` *column_name*=*new_value* [, ...]
`where` *expression*;

Surely we meant Lisp inventor, AI co-founder, and Turing Award winner John McCarthy instead of anti-vaxxer Jenny McCarthy:

```
update author set first_name='John' where last_name='McCarthy';
```

Deleting Table Rows

We can delete table rows with the `delete` command:

`delete from` *table_name* `where` *expression*;

We can also delete an entire table with the `drop table` command:

`drop table` *table_name*;

Be careful with these commands, because they execute without any "are you sure?" message or indication of what will be deleted.

Querying a Database

Querying a database is done with the `select` command, whose general form is:

`SELECT [DISTINCT]` *select_header* `FROM` *source_tables*
`WHERE` *filter_expression*
`GROUP BY` *grouping_expressions* `HAVING` *filter_expression*
`ORDER BY` *ordering_expressions*
`LIMIT` *count* `OFFSET` *count*

- The table is the fundamental data abstraction in a relational database.
- The `select` command returns its result as a table
- Think of a `select` statement as creating a pipeline, each stage of which produces an intermediate *working table*

The `select` Pipeline

The evaluation order of select clauses is approximately:

- `FROM` *source_tables* - Designates one or more source tables and combines them together into one large working table.
- `WHERE` *filter_expression* - Filters specific rows of working table
- `GROUP BY` *grouping_expressions* - Groups sets of rows in the working table based on similar values
- `SELECT` *select_heading* - Defines the result set columns and (if applicable) grouping aggregates.
- `HAVING` *filter_expression* - Filters specific rows of the grouped table. Requires a GROUP BY
- `DISTINCT` - Eliminates duplicate rows.
- `ORDER BY` *ordering_expressions* - Sorts the rows of the result set
- `OFFSET` *count* - Skips over rows at the beginning of the result set. Requires a `LIMIT`.
- `LIMIT` *count* - Limits the result set output to a specific number of rows.

The `from` Clause

The `FROM` clause takes one or more source tables from the database and combines them into one (large) table using the `JOIN` operator. Three kinds of joins:

- `CROSS JOIN`
- `INNER JOIN`
- `OUTER JOIN`

The join is the most important part of a query. We'll discuss cross joins and inner joins, the most important and common joins.

To make our discussion of queries concrete, we'll see examples using a the publication database. Download create-pubs.sql and seed-pubs.sql to play along. The query examples are in query-pubs.sql

Simple `select`s

The simplest `select` query returns all rows from a single table:

```
sqlite> select * from author;
author_id   first_name  last_name
----------  ----------  ----------
1           John        McCarthy
2           Dennis      Ritchie
3           Ken         Thompson
4           Claude      Shannon
5           Alan        Turing
6           Alonzo      Church
```

Notice the * character in the select header. It means return all columns.

Cross Joins

A `CROSS JOIN` matches every row of the first table with every row of the second table. Think of a cross join as a cartesian product.

The general syntax for a cross join is:

`SELECT` ***select_header*** `FROM` ***table1*** `CROSS JOIN` ***table2***

```
sqlite> select * from pub cross join venue;
pub_id  title             venue_id  venue_id  booktitle         month     year
------  ----------------  --------  --------  ----------------  --------  -----
1       Recursive Funct   1         1         Communications    April     1960
1       Recursive Funct   1         2         Communications    July      1974
1       Recursive Funct   1         3         Bell System Tec   July      1948
1       Recursive Funct   1         4         Proceedigns of    November  1936
1       Recursive Funct   1         5         Mind              October   1950
1       Recursive Funct   1         6         Annals of Mathe   Month     1941
2       The Unix Time-s   2         1         Communications    April     1960
2       The Unix Time-s   2         2         Communications    July      1974
2       The Unix Time-s   2         3         Bell System Tec   July      1948
2       The Unix Time-s   2         4         Proceedigns of    November  1936
2       The Unix Time-s   2         5         Mind              October   1950
2       The Unix Time-s   2         6         Annals of Mathe   Month     1941
...
```

Inner Joins

A simple inner join uses an `on` condition.

```
sqlite> select * from pub join venue on pub.venue_id = venue.venue_id;
pub_id      title                   venue_id    venue_id    booktitle       month       year
----------  ----------------------  ----------  ----------  --------------  ----------  -----
1           Recursive Functions of  1           1           Communications  April       1960
2           The Unix Time-sharing   2           2           Communications  July        1974
3           A Mathematical Theory   3           3           Bell System Te  July        1948
4           On computable numbers,  4           4           Proceedigns of  November    1936
5           Computing machinery and 5           5           Mind            October     1950
6           The calculi of lambda-  6           6           Annals of Math  Month       1941
```

Notice that `venue_id` appears twice, becuase we get one from each source table. We can fix that ...

Join Using

The `using` clause, also called a natural join, joins on a like-named column from each table and includes it only once.

```
sqlite> .width 6 15 10 15 6 6
sqlite> select * from pub join venue using (venue_id);
pub_id  title            venue_id    booktitle        month   year
------  ---------------  ----------  ---------------  ------  ------
1       Recursive Funct  1           Communications   April   1960
2       The Unix Time-s  2           Communications   July    1974
3       A Mathematical   3           Bell System Tec  July    1948
4       On computable n  4           Proceedigns of   Novemb  1936
5       Computing machi  5           Mind             Octobe  1950
6       The calculi of   6           Annals of Mathe  Month   1941
```

Notice how we limited the column width in the printout with the `.width` command.

Select Headers

We can limit the columns returned in the final result

```
sqlite> select title, year from pub join venue using (venue_id);
title                                 year
------------------------------------  ---------------
Recursive Functions of Symbolic ...   1960
The Unix Time-sharing System          1974
A Mathematical Theory of Communicat   1948
On computable numbers, with an appl   1936
Computing machinery and intelligenc   1950
The calculi of lambda-conversion      1941
```

The `select title, year` means that the result table will only have those two columns.

Joining Multiple Tables

Remember that we linked the `author` table to the `pub` table using the `author_pub` table to model the many-to-many relationship between authors and publications. We can join all three tables by chaining `join` clauses:

```
sqlite> select * from author join author_pub using (author_id) join pub using (pub_id);
author_id   first_name       last_nam  pub_id     author_position  title     venue
----------  ---------------  --------  ---------  ---------------  --------  -----
1           John             McCarthy  1          1                Recursiv  1
2           Dennis           Ritchie   2          1                The Unix  2
3           Ken              Thompson  2          2                The Unix  2
4           Claude           Shannon   3          1                A Mathem  3
5           Alan             Turing    4          1                On compu  4
5           Alan             Turing    5          1                Computin  5
6           Alonzo           Church    6          1                The calc  6
```

where Clauses

We can filter the results using a `where` clause.
"Which papers did Turing write?"

```
sqlite> select first_name, last_name, title
   ...>   from author join author_pub using (author_id) join pub using (pub_id)
   ...>   where last_name = 'Turing';
first_name  last_name   title
----------  ----------  ------------------------------------------------------------
Alan        Turing      On computable numbers, with an application ro the Entscheidu
Alan        Turing      Computing machinery and intelligence
```

Here we get only the publications by Turing.

like and distinct

Our where condition can match a pattern with like. Use a % for wildcard, i.e., matching any character sequence.
"Which papers did Turing write?"

```
sqlite> select booktitle from venue where booktitle like 'Communications%';
booktitle
-------------------------
Communications of the ACM
Communications of the ACM
```

Notice that the query returned both entries (two different months). We can get distinct rows by adding distinct before the select header:

```
sqlite> select distinct booktitle from venue where booktitle like 'Communications%';
booktitle
-------------------------
Communications of the ACM
```

The glob operator is like the like operator, but uses * as its wildcard character.

`group by` and Aggregate Functions

The `group by` clause groups the results in the working table by the specified column value

- we can apply an aggregate function to the resulting groups
- if we don't apply an aggregate function, only the last row of a group is returned
  - Since the order of rows unspecified, failing to apply an aggregate function would essentially give us a random result

"How many papers did each author write?"

```
sqlite> select author_id, last_name, count(author_id)
   ...>  from author join author_pub using (author_id) join pub using (pub_id)
   ...>  group by author_id;
author_id   last_name   count(author_id)
----------  ----------  ----------------
1           McCarthy    1
2           Ritchie     1
3           Thompson    1
4           Shannon     1
5           Turing      2
6           Church      1
```

Sorting, Aliasing, and Limiting

We can use the `order by` clause to sort the result table.
"Who wrote the most papers?"

```
sqlite> select author_id, last_name, count(author_id) as pub_count
   ...>     from author join author_pub using (author_id) join pub using (pub_id)
   ...>     group by author_id
   ...>     order by pub_count desc
   ...>     limit 1;
author_id   last_name   pub_count
----------  ----------  ----------
5           Turing      2
```

Notice that we also used an alias so we could reference the count in the `order by` clause, we sorted in descending order, and we limited the output to 1 so we got only the top result.

Query Exercises

Download the dorms.sql script, which creates and seeds a database of students and dorms. Create a SQLite database with it and write queries to answer the following questions:

- What are the names of all the dorms?
- What is the total capacity (number of spaces) for all dorms?
- Which students are in Armstrong?
- Which student has the highest GPA?
- Which dorm has the most students?
- Which dorm's students have the highest average GPA?

Closing Thoughts

- Relational databases are pervasive
- A firm grasp of SQL is essential to mastering databases
- You now have a good start
- Believe it or not, we've only scratched the surface.
- For JDBC SQLite driver, I've minimally tested this one with positive results: https://bitbucket.org/xerial/sqlite-jdbc