

SQLite, sqlite3, and more

Programming for Statistical Science

Shawn Santo

Supplementary materials

Full video lecture available in Zoom Cloud Recordings

Additional resources

- [SQL Tutorial](#)
- Package `nodbi` [vignette](#)

Recall

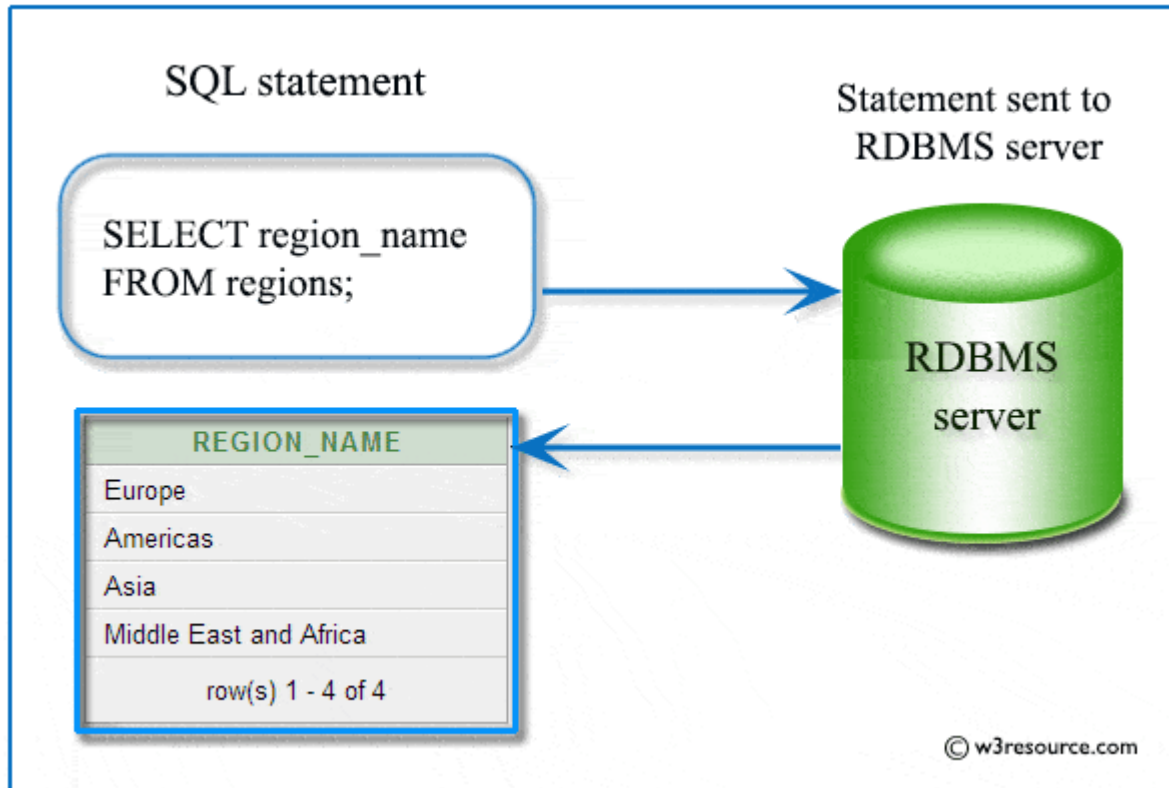
Databases

A **database** is a collection of data typically stored in a computer system. It is controlled by a **database management system (DBMS)**. There may be applications associated with them, such as an API.

Types of DBMS: MySQL, Microsoft Access, Microsoft SQL Server, FileMaker Pro, Oracle Database, and dBASE.

Types of databases: Relational, object-oriented, distributed, NoSQL, graph, and more.

Big picture



Common SQL query structure

Main verbs to get data:

```
SELECT columns or computations  
  FROM table  
  WHERE condition  
  GROUP BY columns  
  HAVING condition  
  ORDER BY column [ASC | DESC]  
  LIMIT offset, count
```

WHERE, GROUP BY, HAVING, ORDER BY, LIMIT are all optional. Primary computations: MIN, MAX, COUNT, SUM, AVG.

We can perform these queries in R with `dbGetQuery()` and `paste()`. This can be done after setting up an in-memory database or connecting to a remote database.

SQL arithmetic and comparison operators

SQL supports the standard +, -, *, /, and % (modulo) arithmetic operators and the following comparison operators.

Operator	Description
=	Equal to
>	Greater than
<	Less than
>=	Greater than or equal to
<=	Less than or equal to
<>	Not equal to

SQL logical operators

Operator	Description
ALL	TRUE if all of the subquery values meet the condition
AND	TRUE if all the conditions separated by AND is TRUE
ANY	TRUE if any of the subquery values meet the condition
BETWEEN	TRUE if the operand is within the range of comparisons
EXISTS	TRUE if the subquery returns one or more records
IN	TRUE if the operand is equal to one of a list of expressions
LIKE	TRUE if the operand matches a pattern
NOT	Displays a record if the condition(s) is NOT TRUE
OR	TRUE if any of the conditions separated by OR is TRUE
SOME	TRUE if any of the subquery values meet the condition

SQLite and `sqlite3`

SQLite **and** sqlite3

SQLite is a software library that provides a relational database management system. The lite in SQLite means light weight in terms of setup, database administration, and required resource.

This is available on the DSS servers. In your terminal

```
[sms185@numeric1 ~]$ which sqlite3  
/usr/bin/sqlite3
```

Check out

```
man sqlite3
```

From the summary:

sqlite3 is a terminal-based front-end to the SQLite library that can evaluate queries interactively and display the results in multiple formats.
sqlite3 can also be used within shell scripts and other applications to provide batch processing features.

Today's data

From your home directory, copy `sql_databases/` from my home directory on the DSS home file system.

```
cp -rf /home/fac/sms185/sql_databases ~/
```

You should see the following in `sql_databases/`:

```
[sms185@geometry2 sql_databases]$ ls  
taxi.sqlite  vet.sqlite
```

Load sqlite3

Load sqlite3 with the database `vet.sqlite`.

```
[sms185@geometry2 sql_databases]$ sqlite3 vet.sqlite
SQLite version 3.26.0 2018-12-01 12:34:55
Enter ".help" for usage hints.
sqlite>
```

Commands in `sqlite3`

1. **Query commands:** `sqlite3` just reads lines of input and passes them on to the SQLite library for execution. This will be the typical command you provide when you want to access, update, and merge data tables.
2. **Dot commands:** these are lines that begin with a dot (".") and are interpreted by the `sqlite3` program itself. These commands are typically used to change the output format of queries, or to execute certain prepackaged query statements.

Both sets of the commands are entered at the prompt: `sqlite>`.

Help

Typing `.help` at the prompt will reveal some of the help features and functions.

```
sqlite> .help
.archive ...           Manage SQL archives
.auth ON|OFF           Show authorizer callbacks
.backup ?DB? FILE      Backup DB (default "main") to FILE
.bail on|off           Stop after hitting an error. Default OFF
.binary on|off         Turn binary output on or off. Default OFF
.cd DIRECTORY          Change the working directory to DIRECTORY
.changes on|off        Show number of rows changed by SQL
.check GLOB            Fail if output since .testcase does not match
.clone NEWDB           Clone data into NEWDB from the existing database

....

.trace FILE|off        Output each SQL statement as it is run
.vfsinfo ?AUX?         Information about the top-level VFS
.vfslist               List all available VFSes
.vfsname ?AUX?         Print the name of the VFS stack
.width NUM1 NUM2 ...   Set column widths for "column" mode
```

Navigating sqlite3

View the current settings

```
sqlite> .show
      echo: off
      eqp: off
    explain: auto
    headers: off
      mode: list
nullvalue: ""
    output: stdout
colseparator: "|"
rowseparator: "\n"
      stats: off
      width:
filename: vet.sqlite
```

List all names and files of attached databases

```
sqlite> .databases  
main: /home/fac/sms185/sql_databases/vet.sqlite
```

List all the tables in the current database

```
sqlite> .tables  
owners      pets        procedure_details  procedure_history
```


Table details

Show the CREATE statements matching the specified table

```
sqlite> .schema owners
CREATE TABLE `owners` (
  `owner_id` REAL,
  `name` TEXT,
  `surname` TEXT,
  `street_address` TEXT,
  `city` TEXT,
  `state` TEXT,
  `state_full` TEXT,
  `zip_code` REAL
);
```

```
sqlite> .schema procedure_details
CREATE TABLE `procedure_details` (
  `procedure_type` TEXT,
  `procedure_sub_code` TEXT,
  `description` TEXT,
  `price` REAL
);
```

```
sqlite> .schema pets
CREATE TABLE `pets` (
  `pet_id` TEXT,
  `name` TEXT,
  `kind` TEXT,
  `gender` TEXT,
  `age` REAL,
  `owner_id` REAL
);
```

```
sqlite> .schema procedure_history
CREATE TABLE `procedure_history` (
  `pet_id` TEXT,
  `date` REAL,
  `procedure_type` TEXT,
  `procedure_sub_code` TEXT
);
```

Note the ; at the end.

Queries

Query commands

Get the first 5 rows from table `owners`. Every query must end with a semicolon.

```
sqlite> SELECT * FROM owners
LIMIT 5;
6049.0|Debbie|Metivier|315 Goff Avenue|Grand Rapids|MI|Michigan|49503.0
2863.0|John|Sebastian|3221 Perry Street|Davison|MI|Michigan|48423.0
3518.0|Connie|Pauley|1539 Cunningham Court|Bloomfield Township|MI|Michigan|48302.0
3663.0|Lena|Haliburton|4217 Twin Oaks Drive|Traverse City|MI|Michigan|49684.0
1070.0|Jessica|Velazquez|3861 Woodbridge Lane|Southfield|MI|Michigan|48034.0
```

How about a nicer output? Change the mode and headers settings.

```
sqlite> .mode column
sqlite> .headers on
sqlite> SELECT * FROM owners
LIMIT 5;
```

owner_id	name	surname	street_address	city	state	state_full	zip_code
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	49503.0
2863.0	John	Sebastian	3221 Perry Stre	Davison	MI	Michigan	48423.0
3518.0	Connie	Pauley	1539 Cunningham	Bloomfield T	MI	Michigan	48302.0
3663.0	Lena	Haliburton	4217 Twin Oaks	Traverse Cit	MI	Michigan	49684.0
1070.0	Jessica	Velazquez	3861 Woodbridge	Southfield	MI	Michigan	48034.0

Revist .show

```
sqlite> .show
      echo: off
      eqp: off
      explain: auto
      headers: on
      mode: column
      nullvalue: ""
      output: stdout
      colseparator: "|"
      rowseparator: "\n"
      stats: off
      width:
      filename: vet.sqlite
```

Examples

How many owners exist for each zip code? Sort the results in descending order and only show the zip codes with at least 3 owners.

```
sqlite> SELECT zip_code, COUNT(zip_code) AS count
        FROM owners
        GROUP BY zip_code
        HAVING count >= 3
        ORDER BY count DESC;
```

zip_code	count
-----	-----
48075.0	11
49503.0	10
48933.0	5
48034.0	4
48219.0	4
48302.0	4
49855.0	4
48342.0	3
48607.0	3

How many of each kind of pet exist? Only output a table with the type of pet and the respective count.

```
sqlite> SELECT kind, COUNT(kind) as n FROM pets  
       GROUP BY kind;
```

kind	n
Cat	31
Dog	57
Parrot	12

Exercise

Which procedure types had an average price exceed \$20? Sort them in descending order by average price. Only output a table with the procedure types and their average price.

procedure_type	avg_price
-----	-----
GENERAL SURGERIES	312.526315789474
ORTHOPEDIC	196.333333333333
OFFICE FEES	52.0
HOSPITALIZATION	25.0

Creating new tables from existing tables

Create with command `CREATE TABLE`

```
sqlite> CREATE TABLE owners_lansing(  
    owner_id REAL,  
    name TEXT,  
    surname TEXT);
```

We are specifying the table name, `owners_lansing`, variables names, and their type.

Add data with command `INSERT INTO`

```
sqlite> INSERT INTO owners_lansing  
    SELECT owner_id, name, surname  
    FROM owners  
    WHERE city = "Lansing";
```


Verify our result is correct

```
sqlite> .tables
owners          pets          procedure_history
owners_lansing  procedure_details
```

```
sqlite> SELECT * FROM owners_lansing;
owner_id      name      surname
-----
7663.0        Julia     Gowan
1653.0        Carolyn   Crane
4793.0        Thomas    Arnold
4110.0        Gregory   Aucoin
3691.0        Richard   Duke
5447.0        Arthur    Reed
```

```
sqlite> SELECT owner_id, name, surname, city
FROM owners
WHERE city = "Lansing";
owner_id      name      surname    city
-----
7663.0        Julia     Gowan      Lansing
1653.0        Carolyn   Crane      Lansing
4793.0        Thomas    Arnold     Lansing
4110.0        Gregory   Aucoin     Lansing
3691.0        Richard   Duke       Lansing
5447.0        Arthur    Reed       Lansing
```

Joins

Join tables

```
sqlite> SELECT owner_id, name, surname
        FROM owners
        ORDER BY owner_id
        LIMIT 10;
```

owner_id	name	surname
1070.0	Jessica	Velazquez
1132.0	Rosa	Quarles
1202.0	Susan	Jackson
1306.0	Benjamin	Spears
1312.0	Charles	Chidester
1319.0	Joe	Custer
1334.0	Jason	Cantwell
1546.0	Joseph	Blow
1653.0	Carolyn	Crane
1766.0	Doris	Ray

```
sqlite> SELECT name, kind, owner_id
        FROM pets
        ORDER BY owner_id
        LIMIT 10;
```

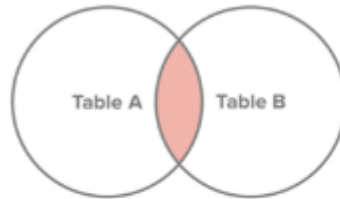
name	kind	owner_id
Biscuit	Dog	1070.0
Stowe	Cat	1132.0
Enyo	Cat	1202.0
Danger	Dog	1306.0
Collette	Dog	1306.0
Rumba	Cat	1312.0
Heisenberg	Dog	1319.0
Crockett	Dog	1334.0
Blackie	Dog	1546.0
Cookie	Cat	1653.0

We can see that Biscuit belongs to Jessica and Benjamin owns two pets - Danger and Collette.

How can we merge these two tables?

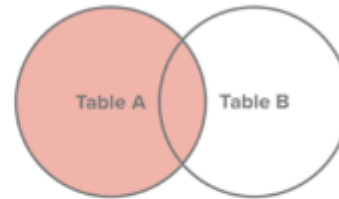
Some joins visualized

Inner Join



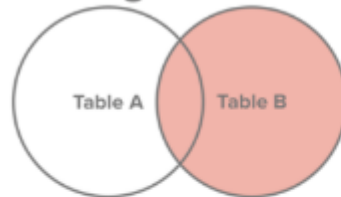
Select all records from Table A and Table B, where the join condition is met.

Left Join



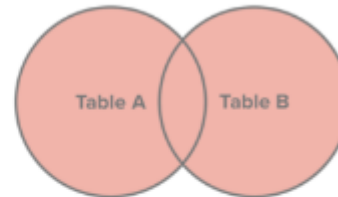
Select all records from Table A, along with records from Table B for which the join condition is met (if at all).

Right Join



Select all records from Table B, along with records from Table A for which the join condition is met (if at all).

Full Join



Select all records from Table A and Table B, regardless of whether the join condition is met or not.

Default join

```
sqlite> SELECT *  
...> FROM owners  
...> JOIN pets  
...> LIMIT 10;
```

owner_id	name	surname	street_address	city	state	state_full	zip_
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	4950
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	4950
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	4950
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	4950
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	4950
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	4950
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	4950
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	4950
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	4950
6049.0	Debbie	Metivier	315 Goff Avenue	Grand Rapids	MI	Michigan	4950

What happened with this join? Do you see anything wrong with our result?

By default, a cross join was used, and it combines every row from the first table with every row from the second table to form the resulting table.

Natural join

```
sqlite> SELECT * FROM owners
      NATURAL JOIN pets;
```

owner_id	name	surname	street_address	city	state	state_full	zip_code
2809.0	Bruce	Dunne	4119 Kimberly Way	Grand Rapids	MI	Michigan	49503

What happened with this join?

In the `NATURAL JOIN`, all the columns from both tables with the same names will be matched against each other. It automatically tests for equality between the values of every column that exists in both tables.

```
sqlite> .schema owners
CREATE TABLE `owners` (
  `owner_id` REAL,
  `name` TEXT,
  `surname` TEXT,
  `street_address` TEXT,
  `city` TEXT,
  `state` TEXT,
  `state_full` TEXT,
  `zip_code` REAL
);
```

```
sqlite> .schema pets
CREATE TABLE `pets` (
  `pet_id` TEXT,
  `name` TEXT,
  `kind` TEXT,
  `gender` TEXT,
  `age` REAL,
  `owner_id` REAL
);
```

Be explicit on your (inner) join

Inner join conditions can be set with the USING verb.

```
sqlite> SELECT owner_id, name, surname, name, kind
        FROM owners
        JOIN pets
        USING (owner_id)
        ORDER BY owner_id
        LIMIT 10;
```

Error: ambiguous column name: name

```
sqlite> SELECT owner_id, owners.name, surname, pets.name, kind
        FROM owners
        JOIN pets
        USING (owner_id)
        ORDER BY owner_id
        LIMIT 10;
```

owner_id	name	surname	name	kind
1070.0	Jessica	Velazquez	Biscuit	Dog
1132.0	Rosa	Quarles	Stowe	Cat
1202.0	Susan	Jackson	Enyo	Cat
1306.0	Benjamin	Spears	Collette	Dog
1306.0	Benjamin	Spears	Danger	Dog
1312.0	Charles	Chidester	Rumba	Cat
1319.0	Joe	Custer	Heisenberg	Dog
1334.0	Jason	Cantwell	Crockett	Dog
1546.0	Joseph	Blow	Blackie	Dog
1653.0	Carolyn	Crane	Cookie	Cat

Left join

Perform a left join with owners and pets.

```
sqlite> SELECT *  
...> FROM owners  
...> LEFT JOIN pets  
...> ON owners.owner_id = pets.owner_id  
...> ORDER BY owner_id  
...> LIMIT 10;
```

owner_id	name	surname	street_address	city	sta
1070.0	Jessica	Velazquez	3861 Woodbridge Lane	Southfield	MI
1132.0	Rosa	Quarles	4791 Tennessee Avenu	Southfield	MI
1202.0	Susan	Jackson	3677 Daylene Drive	Livonia	MI
1306.0	Benjamin	Spears	1507 Twin Oaks Drive	Clam River	MI
1306.0	Benjamin	Spears	1507 Twin Oaks Drive	Clam River	MI
1312.0	Charles	Chidester	4086 Cottonwood Lane	Dutton	MI
1319.0	Joe	Custer	2765 Wildrose Lane	Westland	MI
1334.0	Jason	Cantwell	2372 Don Jackson Lan	Southfield	MI
1546.0	Joseph	Blow	556 D Street	Southfield	MI
1653.0	Carolyn	Crane	3952 Jarvisville Roa	Lansing	MI


```

sqlite> SELECT *
...> FROM pets
...> LEFT JOIN owners
...> USING (owner_id)
...> ORDER BY owner_id
...> LIMIT 10;

```

pet_id	name	kind	gender	age	owner_id	r
U8-6473	Biscuit	Dog	female	3.0	1070.0	c
T2-2142	Stowe	Cat	female	15.0	1132.0	F
N7-6805	Enyo	Cat	female	12.0	1202.0	S
F2-3235	Danger	Dog	male	8.0	1306.0	F
L2-1834	Collette	Dog	female	4.0	1306.0	F
L4-4205	Rumba	Cat	male	5.0	1312.0	C
J2-3320	Heisenberg	Dog	male	3.0	1319.0	c
J0-7893	Crockett	Dog	male	12.0	1334.0	c
U6-4890	Blackie	Dog	male	6.0	1546.0	c
P9-6519	Cookie	Cat	female	6.0	1653.0	C

SQLite does not support a RIGHT JOIN.

Exercises

Which owners have multiple pets? Sort your table so the count is in descending order. Only output a table with the owners' name, surname and number of pets.

owner_name	owner_surname	pet_count
-----	-----	-----
Lee	McKenzie	3
Charles	Swarey	3
Stacey	Randolph	3
Benjamin	Spears	2
Robert	Partridge	2
Mario	Riddle	2
Elvia	Warren	2
Gary	Snider	2

Which pet under the age of 10 had the most procedures according to the procedure history? Only return a table with the pet's name, kind, age, and number of procedures.

name	kind	age	procedure_count
-----	-----	-----	-----
Bonaparte	Dog	4.0	3

Finer details

SQL statement processing

What happens in the background when a SQL statement is sent to the RDBMS?

1. The SQL statement is parsed around key words.
2. The statement is validated. Do all tables and fields exist? Are names unambiguous?
3. The RDBMS optimizes and eventually generates an access plan - how best to retrieve the data, update the data, or delete the data.
4. The access plan is executed.

Subqueries

A subquery may occur in a

- SELECT clause
- FROM clause
- WHERE clause

The inner (sub) query executes first before its parent query so that the results of an inner query can be passed to the outer query.

```
sqlite> SELECT *  
        FROM pets  
        WHERE pet_id IN (  
            SELECT pet_id FROM procedure_history  
            WHERE procedure_type = "ORTHOPEDIC"  
        );
```

What are we trying to get with the above query?

Tips

- On very large datasets use indices to speed up searches.
- Use `CAST` to change data types in a query.
- Attach databases to perform `JOIN` operations on tables across databases.
- See your query and improve performance with `EXPLAIN QUERY PLAN` followed by your query.

Beyond SQL: NoSQL

- Document
- Graph stores
- Key-value stores
- Wide-column stores

R package `nodbi` provides a single user interface for interacting with many NoSQL databases. This is similar to package `DBI` for interacting with relational databases that use SQL.

R package `nodbi` supports:

- MongoDB
- Redis (server based)
- CouchDB
- Elasticsearch
- SQLite

Check out their vignette for more information: <https://docs.ropensci.org/nodbi/>

References

1. SQL Join Types — SQL Joins Explained. (2020). <http://www.sql-join.com/sql-join-types>.
2. SQL Tutorial - w3resource. (2020). <https://www.w3resource.com/sql/tutorials.php>.
3. What is NoSQL? NoSQL Databases Explained. (2020). <https://www.mongodb.com/nosql-explained>.