# Intro to Programming for Public Policy Week 9 Relational Databases and SQL

Eric Potash

May 22, 2018



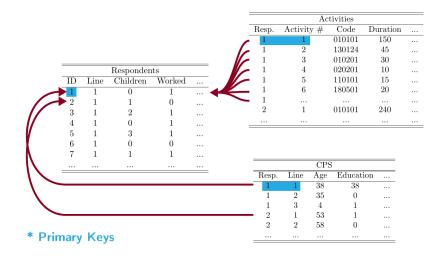
#### Databases as Infrastructure

- Since they are not consumer-facing, the importance of databases as a technological infrastructure is not widely appreciated.
- ► They are a key component in most applications including websites, health records, supply chains, etc.

## Why databases?

- ▶ Databases efficiently store and retrieve data.
  - ► Typical computers have about 8GB memory, a hard limit on what you can simultaneously load.
  - Databases allow efficient row-wise operations
  - Efficiently search hundreds of GB of data
  - Maintain one copy of the data and allow many people to access it (database server)

# Example: American Time Use Survey (ATUS)



#### Relational databases

#### Most databases use a relational model:

- ▶ Data are stored in tables
- ► Tables are linked using *keys*
- ► Interact with database using Structured Query Language (SQL)

# Why not relational databases?

- Extremely large datasets (thousands of gigabytes)
- ▶ Not all data is relational (there are databases for that, too!)
- Not all tasks are database tasks (e.g. file manipulation, networking, image processing)

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- The values in a row should refer uniquely to the key, not to a non-key attribute.
  - e.g. the activities table should not include both the activity code and its definition.

## Good practice

- ► Each table should contain a single logical element, without repetition.
- Meaningful and carefully selected primary key.
- Appropriate primary keys are what allow databases to work efficiently.

### Database concepts

- Tables
- Variables
  - Types
- Constraints
  - Unique
  - ► Non-null
  - Primary key
  - Foreign key

The collection of tables, variables and constraints together define a database *schema*.

Structured Query Language (SQL)

## **SQL** Overview

- ▶ The most popular model among databases is relational. These systems are called *RDBMS*s.
- ▶ SQL is the standardized language for working with an RDBMS.
- Originally intended to be user-facing and fairly "intuitive".
- Despite standardization, the implementations (e.g. Oracle, PostgreSQL, SQLite) all have some differences.

## Running SQLite

Download the atus.sqlite file then run this at the command line (in the same directory as the downloaded file):

```
$ sqlite3 atus.sqlite
SQLite version 3.13.0 2016-05-18 10:57:30
Enter ".help" for usage hints.
sqlite>
```

## Navigating SQLite

The biggest differences between RDBMSs are accessing the metadata. To show tables in the database:

```
sqlite> .tables activities cps respondents roster
```

#### Table schema

To show the schema of a table (its columns and types):

```
sqlite> .schema --indent cps
CREATE TABLE cps(
  case id INTEGER,
  line_no INTEGER,
  family_income INTEGER,
  educational_attainment INTEGER,
 duration of masters INTEGER,
 years_in_college INTEGER,
 marital_status INTEGER,
  state code INTEGER,
  age INTEGER,
 years_education INTEGER,
 PRIMARY KEY(case id, line no)
```

Possible types: integer, real (float), text (string)

# Full schema sqlite> .

sqlite> .fullschema --indent CREATE TABLE roster( case id INTEGER, line no INTEGER, how related INTEGER, edited\_age INTEGER, edited\_sex INTEGER, PRIMARY KEY(case\_id, line\_no) CREATE TABLE respondents( case id INTEGER, line no INTEGER, daily time alone INTEGER, daily time secondary childcare hh or own children INTEGE worked last week INTEGER, daily time with family INTEGER, daily\_time\_with\_friends INTEGER, daily time secondary childcare hh children INTEGER,

#### Data dictionaries

- ► ATUS Data Dictionary:
  - ▶ family\_income: p. 14
  - educational\_attainment: p. 28
  - ▶ marital\_status: p. 59
- ► ATUS Lexicon

## Selecting columns

To see all of the data in the cps table:

```
SELECT * FROM cps;
```

To see just two of the columns:

```
SELECT marital_status, years_education FROM cps;
```

#### Notes:

- Queries end with a semi-colon
- Upper case keywords (SELECT, FROM, etc.) are a convention but not necessary.
- No whitespace requirements.

## Query output

```
sqlite> SELECT * from cps;
...
20151212152498|1|11|43|-1|-1|1|39|37|17
20151212152498|2|11|43|-1|-1|1|39|34|17
20151212152498|3|11|-1|-1|-1|39|8|-1
20151212152498|4|11|-1|-1|-1|39|5|-1
```

You may prefer the output after changing these settings:

```
sqlite> .mode columns
sqlite> .headers on
```

#### LIMIT

Akin to head in the command line and pandas, use the SQL keyword LIMIT to restrict output:

SELECT \* FROM cps LIMIT 10;

#### WHERE

To restrict to rows satisfying a certain condition use a WHERE clause.

▶ when years\_education = -1 the education variable is missing:

```
SELECT years_education
FROM cps
WHERE years_education > -1;
```

▶ Use AND, OR, NOT to perform boolean logic, as in python:

Comment to end of line using -- (akin to # in python)

#### ORDER BY

Can sort results by a column (defaults to ascending):

```
SELECT * FROM cps
ORDER BY family_income;
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To make it descending:

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SELECT * FROM cps
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▶ To make it descending:

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SELECT * FROM cps
ORDER BY family_income DESC;
```

Combine with LIMIT as to find top or bottom:

```
SELECT * FROM cps
ORDER BY family_income DESC
LIMIT 10;
```

#### COUNT

Very useful aggregate function is COUNT:

```
SELECT COUNT(*) FROM cps
WHERE educational_attainment > -1;
```

An aggregate function is one that returns a single row for the table.

#### **COUNT** details

- ► Could do COUNT(family\_income) or COUNT(age) to count the number of non-null values in the given column.
- ▶ In this data nothing is null, missingness is represented by -1.
- ► COUNT(\*) counts all rows.

## More aggregates

▶ To calculate the average value of a column:

```
SELECT AVG(age) FROM cps;
```

► To get the maximum:

```
SELECT MAX(age) FROM cps;
```

And minimum:

```
SELECT MIN(age) FROM cps;
```

Combine them:

```
SELECT MIN(age), AVG(age), MAX(age)
FROM cps;
```

## Booleans and aggregation

To find the proportion of respondents whose educational attainment is available that have a bachelors degree:

```
SELECT AVG(educational_attainment > 42)
FROM cps
WHERE educational_attainment > 0;
```