The Relational Model and the Structured Query Language

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Who are these dudes?


ORACLE®

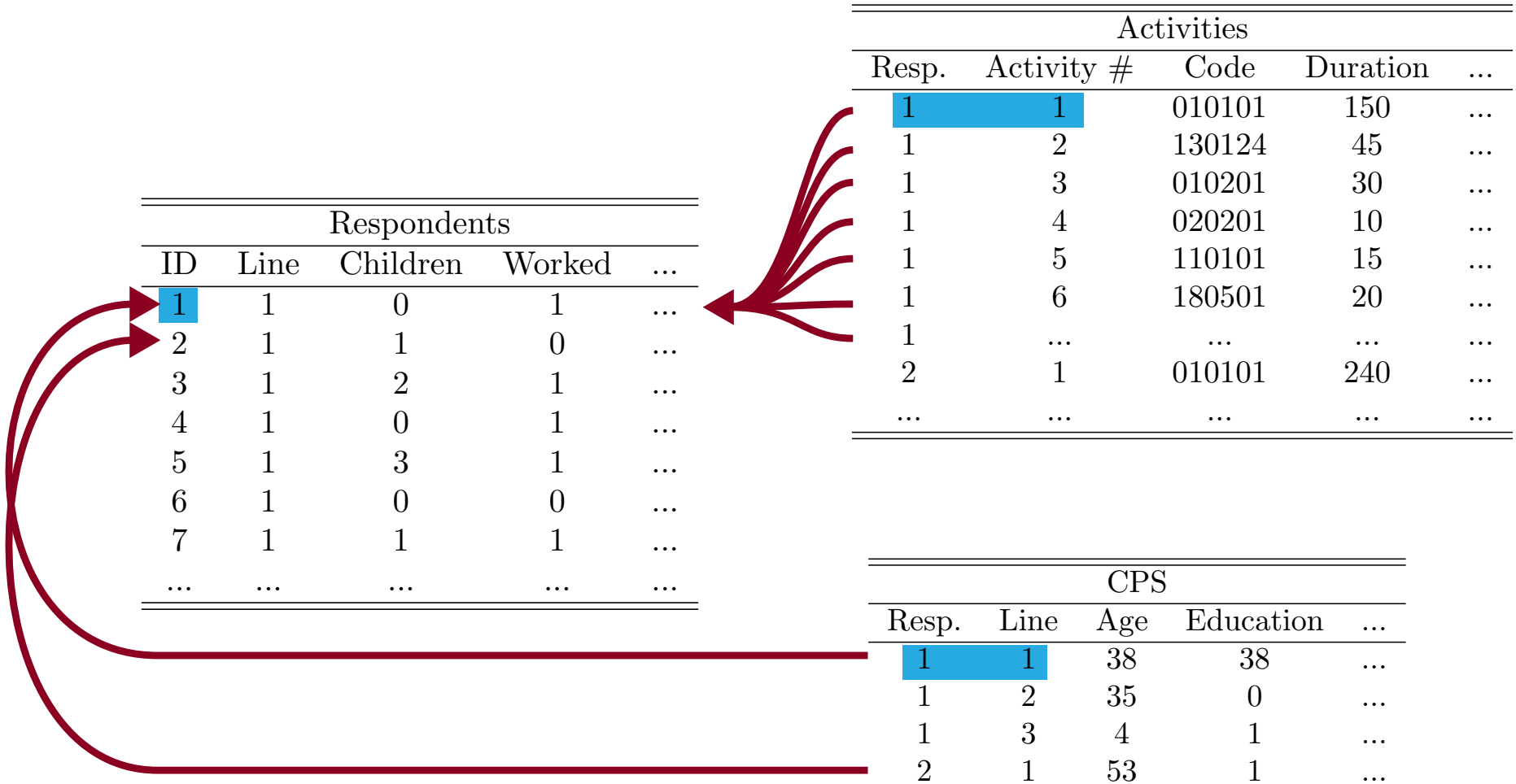
Databases: Content

- As these are not consumer-facing products, database systems fly under the radar like our energy infrastructure. But they are very, very important.
- They power the deep content of the internet: blogs, consumer applications, health services, etc.
  - Typical web application is server + database + scripting language.
- Huge problems in health services, government, etc. from failure to construct consistent or interoperable models.
  - This is totally solvable, but more political than technical!

Databases

- Databases store data efficiently, and retrieve it quickly.
  - Search efficiently over many GBs, or hundreds of GBs of data...
  - Really huge datasets need different models than discussed today.
- In the 'relational model,' the data are stored in interrelated 'tables.'
- Each record (row) is uniquely identified by a 'primary key' (index).
- Differs from composite objects in object-oriented programming, since many records in one table may link to a single record of another (e.g., people to a city) and several records may link in different ways (grade to teacher, student, and school).

RDB: Time Use Survey, Revisited



Respondents

ID	Line	Children	Worked	...
1	1	0	1	...
2	1	1	0	...
3	1	2	1	...
4	1	0	1	...
5	1	3	1	...
6	1	0	0	...
7	1	1	1	...
...	...	...	...	...

Activities

Resp.	Activity #	Code	Duration	...
1	1	010101	150	...
1	2	130124	45	...
1	3	010201	30	...
1	4	020201	10	...
1	5	110101	15	...
1	6	180501	20	...
1	...	...	...	...
2	1	010101	240	...
...	...	...	...	...

CPS

Resp.	Line	Age	Education	...
1	1	38	38	...
1	2	35	0	...
1	3	4	1	...
2	1	53	1	...
2	2	58	0	...
...	...	...	...	...

*** Primary Keys**

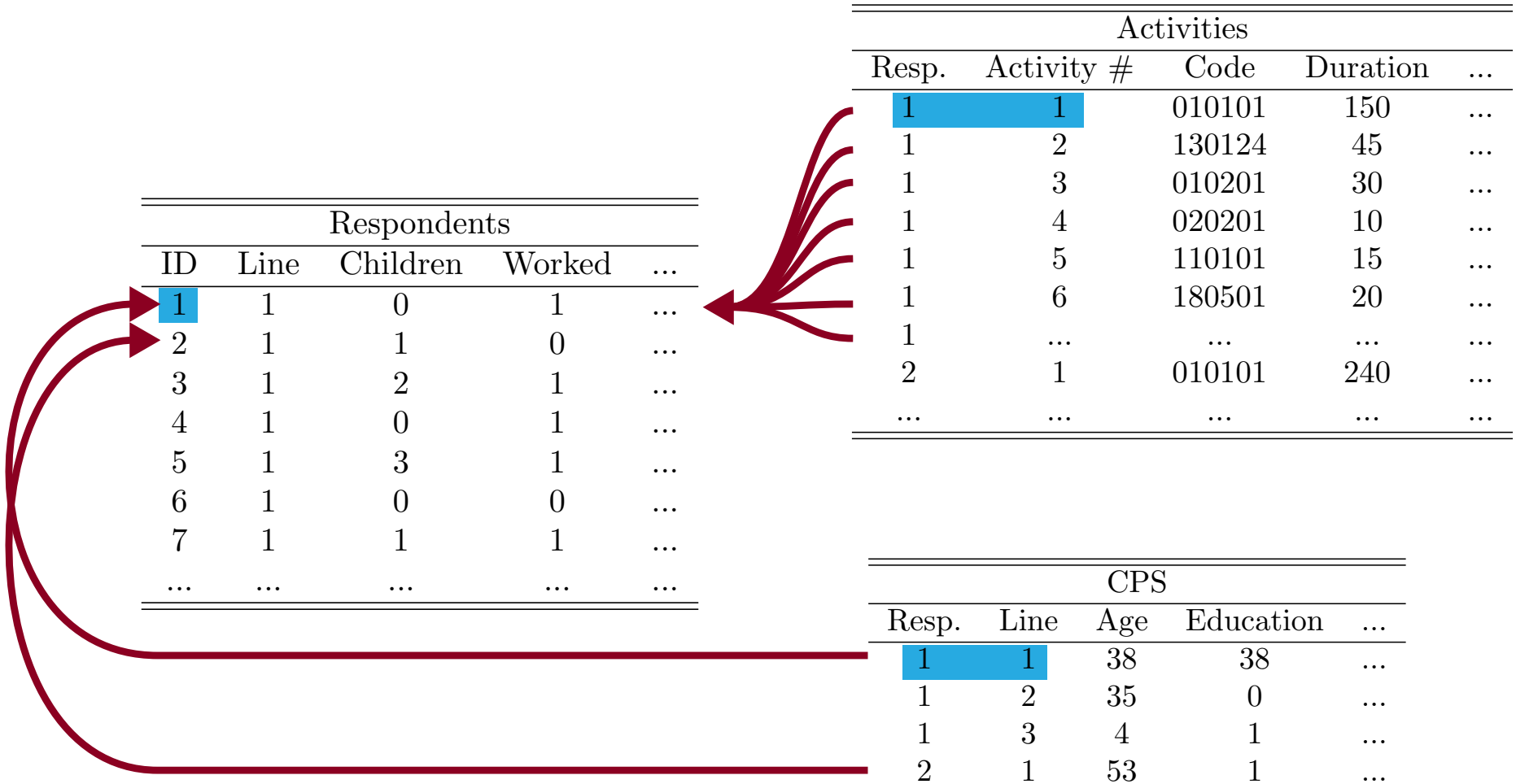
The Relational Model: Normal Forms (Good Practice)

Normal forms are defined by E. F. Codd (1971) as:

1. Each record should be 'atomic' that is, non-divisible. A single row/record, should not contain multiple, divisible pieces.
   - The respondent table should not have a cell with the ages of all household members (stored in a 'roster' file).
2. No non-prime attribute of the table may be dependent on a proper subset of any candidate key.
   - In the time use survey, a respondent ID and activity number jointly identify an activity. The table should not, therefore, contain information on the respondent.
3. The values in a row should refer uniquely to the key – not to a non-key attribute.
   - In the time use activity tables, we should not store both the activity code and its interpretation.

To avoid repeating cumbersome calculations, these are sometimes violated.

RDB: Time Use Survey, Revisited



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*** Primary Keys**

Good Practice, in Practice

- Each table should contain a single logical element, without repetition.
- One MUST take some care to understand what is unique in your table, and use that property to link tables: the primary key.
- Appropriate primary keys are what make databases actually work efficiently.

Using a Database

Relational Database Management Systems (RDBMSs) and the Structured Query Language (SQL)

- Most of the most-prevalent database systems implement the relational model.* These systems are called RDBMSs.
- Structured Query Language (SQL) (ISO/IEC 9075:2011) is a standardized (ISO/ANSI) language for interacting with RDBMSs.
- Originally intended to be user-facing, so 'fairly intuititive.'
- Despite standardization, the implementations almost all have some (extremely annoying) differences: some tinkering is necessary to migrate between 'dialects.'
  - Nevertheless, the basic functionality – selecting, inserting, deleting, and altering data, is pretty consistent.

*There are always exceptions...

(Some of) The Most Prevalent Databases

MariaDB

Microsoft® SQL Server®

PostgreSQL

mongoDB®

(Some of) The Most Prevalent Databases

MariaDB

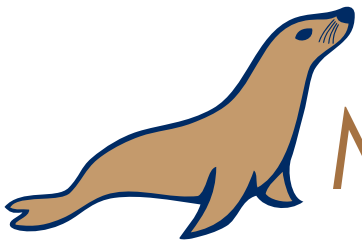
SQLite

Microsoft® SQL Server®

PostgreSQL

NoSQL

(Some of) The Most Prevalent Databases



MariaDB

SQLite

This class.

Microsoft® SQL Server®

PostgreSQL

mongoDB®

Opening SQLite

- To just open a file, do:

```
sqlite3 atus.sqlite
```

- This should give you a new prompt.
- To make the output clearer, you can do:

```
.mode columns
.headers on
```

- You can also run a file, like so:

```
sqlite3 atus.sqlite < ex/limit_cps.sql
```

- We'll talk about interfacing to pandas, on Wednesday

Navigating SQLite: Time Use Survey

The biggest difference between RDBMS implementations is in access to the metadata: a list of tables and their schema (format).

- To show the tables in the database:

```
sqlite> .tables
sqlite> .fullschema --indent
```

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

```
sqlite> .schema cps
```

- Types in SQLite: integer, real (float), text (string), or null.
  - Other RDBMSs have more types – e.g., datetime, or even geographies.
  - SQLite just has date functions.

SELECTing Columns: Vertical Slicing

This is THE basic SQL syntax that you will use.

- Selecting all (*) columns from the cps table:

```
SELECT * FROM cps;
```

- You can also name specific columns:

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

- Each query ends by a semi-colon.

- Upper case keywords an old convention: SQL strings are often used in other languages, and therefore aren't color-highlighted. Not necessary.
- There is absolutely no requirement about the formatting of the query.

LIMIT (i.e., .head())

- Normally, this would come a bit later... but the last output was pretty excessive. For exploration, use 'LIMIT':

```
SELECT * FROM cps LIMIT 10;
```

WHERE Requirements: Horizontal Slicing

- Make requirements with 'WHERE':

```
SELECT years_education
FROM cps
WHERE years_education > 0; /* i.e., exists */
```

- Can make multiple requirements with AND or OR:

```
SELECT years_education, state_code
FROM cps
WHERE years_education > 0 AND
      state_code = 17;
```

- Note the single '=' sign.

GROUP BY (i.e., .groupby())

- This functions exactly as groupby() in pandas.
- 'Group' by one or more variables, to aggregate over others.
  - Unlike most RDBMSs, SQLite won't complain if you mix and match aggregating functions and non-aggregated fields – so be careful.
- Many functions: `AVG`, `SUM`, `MAX`, `MIN`, `COUNT`, etc.

```
SELECT
  number_of_hh_children,
  AVG(daily_time_alone)
FROM
  respondents
GROUP BY
  number_of_hh_children
;
```

ORDER BY (i.e., .sort_values(by = "..."))

- Sort by one or more fields, ascending or descending (ASC or DESC).

```
SELECT
  state_code,
  AVG(educational_attainment > 42) AS Bachelors
FROM cps
WHERE
  educational_attainment > 0 /* i.e., defined */
GROUP BY state_code
ORDER BY Bachelors DESC
LIMIT 10;
```

JOIN (i.e., .join())

- In households with children, what is the likelihood that a spouse or partner is present, by levels of education. Must `JOIN` tables.
- Alternatively, this can be done with multiple tables in '`FROM`' and join conditions under '`WHERE`.'

```
SELECT
  educational_attainment,
  AVG(spouse_or_partner_present == 1) Married,
  COUNT(spouse_or_partner_present == 1) "(N)"
FROM cps
JOIN respondents ON
  cps.case_id = respondents.case_id AND
  cps.line_no = 1
WHERE
  number_of_hh_children > 0
GROUP BY educational_attainment;
```

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```
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  educational_attainment,
  AVG(spouse_or_partner_present == 1) Married,
  COUNT(spouse_or_partner_present == 1) "(N)"
FROM cps,
     respondents
WHERE
  cps.case_id = respondents.case_id AND
  cps.line_no = 1 AND
  number_of_hh_children > 0
GROUP BY educational_attainment;
```

Subqueries

- You can use subqueries as tables, for multiple levels of grouping.
- How much time does each sex claim to spend in 'Personal/Private activities' such as 'necking' and 'private activity, unspecified'?

```
SELECT ID, COUNT(id), AVG(activity) FROM (
  SELECT
    roster.case_id, AVG(edited_sex) id,
    SUM((activity_code = 10401) * (duration))
      AS activity
  FROM roster
  INNER JOIN activities ON
    roster.case_id = activities.case_id
  WHERE roster.line_no = 1 AND
        18 < edited_age AND edited_age < 45
  GROUP BY roster.case_id
) GROUP BY id;
```

On The Structure

- Good news is: SQL queries basically always follow the same structure.
- You may or may not need all the pieces, but there's no question about the order– there's only one way.
- The query on the last page is as complicated as it gets.