Big Data and Economics

Tips for Managing Data

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Prologue

Prologue

Today we'll focus on grappling with data

- File formats and extensions
- Archiving & file compression
- Dictionaries (hash tables)
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You're gonna need to know how to do a lot of this!

File formats

A note on file extensions

- Often, if you download a file, you will immediately understand what type of a file it is by its extension
- File extensions in and of themselves don't serve any particular purpose other than convenience
- File extensions were created so that humans could keep track of which files on their workspace are scripts, which are binaries, etc.

Why is the file format important?

- File formats matter because they may need to match the environment you're working in
- If you use the wrong file format, it may cause your computations to run slower than otherwise
- To the extent that the environment you're working in requires a specific file format, then using the correct format is essential

Common file extensions when working

- In the following table, I list some of the most common file extensions
- For a more complete list of almost every file extension imaginable (note: they missed Stata's `.do` and `.dta` formats), see here.
- Another great discussion about file formats is here on stackexchange

Open-format file extensions

The following file extensions are not tied to a specific software program

- In this sense they are "raw" and can be viewed in any sort of text editor

File extension	Description
CSV	Comma separated values; data is in tabular form with column breaks marked by commas
TSV	Tab separated values; data is in tabular form with column breaks marked by tabs
DAT	Tab-delimited tabular data (ASCII file)
TXT	Plain text; not organized in any specific manner (though usually columns are delimited with tabs or commas)

Examples of CSV, TSV, XML, YAML, and

A possible JSON representation describing a person (source)

```
{
  "firstName": "John",
  "lastName": "Smith",
  "isAlive": true,
  "age": 27,
  "address": {
    "streetAddress": "21 2nd Street",
    "city": "New York",
    "state": "NY",
    "postalCode": "10021-3100"
  },
  "phoneNumbers": [
    {
      "type": "home",
      "number": "212 555-1234"
    },
    {
```

Examples of CSV, TSV, XML, YAML, and

The same example as previously, but in XML: (source)

```xml
<person>
  <firstName>John</firstName>
  <lastName>Smith</lastName>
  <age>25</age>
  <address>
    <streetAddress>21 2nd Street</streetAddress>
    <city>New York</city>
    <state>NY</state>
    <postalCode>10021</postalCode>
  </address>
  <phoneNumber>
    <type>home</type>
    <number>212 555-1234</number>
  </phoneNumber>
  <phoneNumber>
    <type>fax</type>
    <number>646 555-4567</number>
```

Examples of CSV, TSV, XML, YAML, and

The same example, but in YAML: (source)

```yaml
firstName: John
lastName: Smith
age: 25
address:
  streetAddress: 21 2nd Street
  city: New York
  state: NY
  postalCode: '10021'
phoneNumber:
- type: home
  number: 212 555-1234
- type: fax
```

Note that the JSON code above is also valid YAML; YAML simply has an alternative syntax that makes it more human-readable

Proprietary file extensions

The following file extensions typically require additional software to read, edit, or convert to another format

File extension	Description
DB	A common file extension for tabular data for SQLite
SQLITE	Another common file extension for tabular data for SQLite
XLS, XLSX	Tab-delimited tabular data for Microsoft Excel
RDA, RDATA	Tabular file format for R
MAT	... for Matlab
SAS7BDAT	... for SAS
SAV	... for SPSS
DTA	... for Stata

Tips for opening files with r

- If you're working with tabular data, you can use the `read_csv()` function from the **readr** (tidyverse) package or `fread` from **data.table**
- If you're working with a proprietary file format, you can use the `read_*()` functions from the **haven** package
- If you're reading in any table format, `read_table()` might work!
- If you're working with a JSON file, you can use the **jsonlite** package
- When in doubt, Google/ChatGPT "How do I open file .XXX in R?"
    - I bet you someone has already needed to solve this problem

```
df_csv   ← read_csv('https://www2.census.gov/ces/opportunity/national_percentile_outcomes.csv')
df_fread   ← data.table::fread('https://www2.census.gov/ces/opportunity/national_percentile_outcomes.csv')
df_stata ← haven::read_dta('https://www2.census.gov/ces/opportunity/national_percentile_outcomes.dta')

head(df_csv)
```

```
## # A tibble: 6 × 3,914
##   par_pctile kfr_pooled_pooled kir_pooled_pooled jail_pooled_pooled
##        <dbl>             <dbl>             <dbl>              <dbl>
## 1          1             0.305             0.34              0.0559
## 2          2             0.317             0.352             0.0503
## 3          3             0.326             0.360             0.0463
## 4          4             0.333             0.367             0.0445
## 5          5             0.338             0.371             0.0417
## 6          6             0.342             0.375             0.0405
## # ℹ 3,910 more variables: married_asian_female_n <dbl>,
## #   married_asian_female <dbl>, s_married_asian_female <dbl>,
## #   imp_married_asian_female <dbl>, working_asian_female_n <dbl>,
## #   working_asian_female <dbl>, s_working_asian_female <dbl>,
## #   imp_working_asian_female <dbl>, has_dad_asian_female_n <dbl>,
## #   has_dad_asian_female <dbl>, s_has_dad_asian_female <dbl>,
## #   imp_has_dad_asian_female <dbl>, kir_top20_asian_female_n <dbl>, …
```

Help! This file froze my computer!

- Sometimes we'll be reading quite large files
  - These can be too big to fit in memory

Just read in a single row to see the column names:

```
# I need to sete an environment variable to increase the size of the connection
# R will complain if you try to read in a file that's too big
# This will reset when I close this session.
Sys.setenv("VROOM_CONNECTION_SIZE"=1e6)
df ← read_csv('https://www2.census.gov/ces/opportunity/cz_outcomes.csv',n_max=1)
```

```
## Rows: 1 Columns: 10825
## ── Column specification ────────────────────────────────────────────────────
## Delimiter: ","
## chr    (1): czname
## dbl (9658): cz, kir_natam_female_p1, kir_natam_female_p25, kir_natam_female_ ...
## lgl (1166): proginc_natam_female_p1, proginc_natam_female_p25, proginc_natam ...
##
## ℹ Use spec() to retrieve the full column specification for this data.
## ℹ Specify the column types or set show_col_types = FALSE to quiet this message.
```

- You can and should also consult the codebook (remember those?)

Help! This file froze my computer!

Once you know your columns, read those in:

```
Sys.setenv("VROOM_CONNECTION_SIZE"=1e6)
read_csv('https://www2.census.gov/ces/opportunity/cz_outcomes.csv',
  col_select=c('cz', 'kfr_pooled_pooled_p1', 'kfr_pooled_pooled_p25',
  'kfr_pooled_pooled_p50','kfr_pooled_pooled_p75','kfr_pooled_pooled_p100'))
```

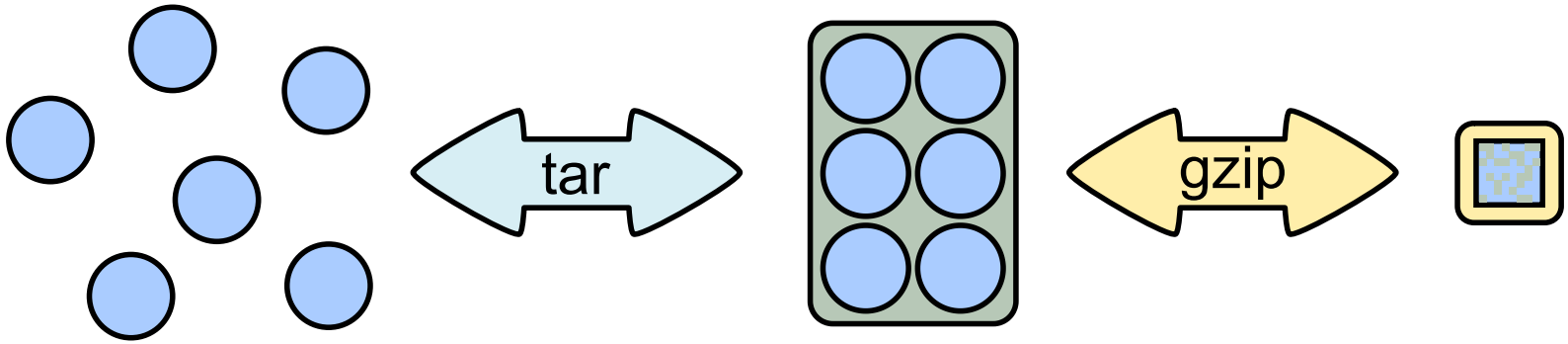
```
## # A tibble: 741 × 6
##       cz kfr_pooled_pooled_p1 kfr_pooled_pooled_p25 kfr_pooled_pooled_p50
##    <dbl>                <dbl>                 <dbl>                 <dbl>
##  1   100                0.260                 0.364                 0.461
##  2   200                0.264                 0.363                 0.456
##  3   301                0.286                 0.380                 0.467
##  4   302                0.262                 0.366                 0.462
##  5   401                0.251                 0.359                 0.459
##  6   402                0.249                 0.362                 0.466
##  7   500                0.241                 0.352                 0.454
##  8   601                0.283                 0.384                 0.478
##  9   602                0.267                 0.382                 0.489
## 10   700                0.240                 0.351                 0.454
## # ℹ 731 more rows
## # ℹ 2 more variables: kfr_pooled_pooled_p75 <dbl>, kfr_pooled_pooled_p100 <dbl>
```

Archiving & file compression

Archiving & file compression

Because data can be big and bulky, it is often easier to store and share the data in compressed form

File extension	Description
ZIP	The most common format for file compression



Other file types that aren't data

- There are many file types that don't correspond to readable data. For example, script files (e.g. `.R`, `.py`, `.jl`, `.sql`, `.do`, `.cpp`, `.f90`, ...) are text files with convenient extensions to help the user remember which programming language the code is in
- As a rule of thumb, if you don't recognize the extension of a file, it's best to inspect the file in a text editor (though pay attention to the size of the file as this can also help you discern whether it's code or data)

General Types of Data

- When you think of data, you probably think of rows and columns, like a matrix or a spreadsheet
- But it turns out there are other ways to store data, and you should know their similarities and differences to tabular data

Can I just read a zip directly in?

- Yes, but it's a little more complicated
- And you can may still want to read in a few rows or columns like before

```
download.file('https://www2.census.gov/ces/opportunity/county_outcomes.zip','county_outcomes.zip')
read_csv(unz('county_outcomes.zip','county_outcomes.csv'),
  col_select=c('county','kfr_pooled_pooled_p1','kfr_pooled_pooled_p25',
  'kfr_pooled_pooled_p50','kfr_pooled_pooled_p75','kfr_pooled_pooled_p100'))
```

```
## # A tibble: 3,219 × 6
##    county kfr_pooled_pooled_p1 kfr_pooled_pooled_p25 kfr_pooled_pooled_p50
##     <dbl>                <dbl>                 <dbl>                 <dbl>
##  1      1                0.245                 0.362                 0.471
##  2      3                0.292                 0.389                 0.479
##  3      5                0.233                 0.349                 0.457
##  4      7                0.249                 0.363                 0.469
##  5      9                0.293                 0.392                 0.483
##  6     11                0.244                 0.346                 0.440
##  7     13                0.231                 0.357                 0.474
##  8     15                0.256                 0.362                 0.461
##  9     17                0.236                 0.341                 0.437
## 10     19                0.265                 0.365                 0.459
## # ℹ 3,209 more rows
## # ℹ 2 more variables: kfr_pooled_pooled_p75 <dbl>, kfr_pooled_pooled_p100 <dbl>
```

```
# Delete the file
file.remove('county_outcomes.zip')
```

```
## [1] TRUE
```

Dictionaries

Dictionaries (a.k.a. Hash tables)

- A dictionary is a list that contains `keys` and `values`
- Each key points to one value
- While this may seem like an odd way to store data, it turns out that there are many, many applications in which this is the most efficient way to store things
- We won't get into the nitty gritty details of dictionaries, but they are the workhorse of computer science, and you should at least know what they are and how they differ from tabular data
- In fact, dictionaries are often used to store multiple arrays in one file (e.g. Matlab `.mat` files, R `.RData` files, etc.)

Dictionaries (a.k.a Hash tables) in R

- Dictionraies are a little clunky in R
- You'll mainly use them as lists or vectors

```
phone_numbers_list ← list('Jenny'='1 (623) 867-5309',
  'Rejection Hotline'='1 (518) 935-4012',
  'Santa'='1 (951) 262-3062')

print(phone_numbers_list)
```

```
## $Jenny
## [1] "1 (623) 867-5309"
##
## $Rejection Hotline
## [1] "1 (518) 935-4012"
##
## $Santa
## [1] "1 (951) 262-3062"
```

Why are dictionaries useful?

- You might look at the previous example and think a vector would be a better way to store phone numbers
- The power of dictionaries is in their **lookup speed**
- Looking up an index in a dictionary takes the same amount of time no matter how long the dictionary is!
    - Computer scientists call this $O(1)$ access time
- Moreover, dictionaries can index **objects**, not just scalars
- So I could have a dictionary of data frames, a dictionary of arrays, ...

Big Data File Types

Big Data file types

- Big Data file systems like Hadoop and Spark often use the same file types as R, SQL, Python, and Julia
- That is, `CSV` and `TSV` files are the workhorse
- Because of the nature of distributed file systems (which we will discuss in much greater detail next time), it is often the case that JSON and XML are not good choices because they can't be broken up across machines
- Note: there is a distinction between JSON files and JSON records; see the second link at the end of this document for further details

Big Data File Types

Sequence

- Sequence files are dictionaries that have been optimized for Hadoop and friends
- The advantage to taking the dictionary approach is that the files can easily be coupled and decoupled

Avro

- Avro is an evolved version of Sequence---it contains more capability to store complex objects natively

Parquet

- Parquet is a format that allows Hadoop and friends to partition the data column-wise (rather than row-wise)
- Other formats in this vein are RC (Record Columnar) and ORC (Optimized Record Columnar)

Useful Links

- A beginner's guide to Hadoop storage formats
- Hadoop File Formats: It's not just CSV anymore

Your challenge

- With time left, try to download each of the following files to a folder and read them in:
  - https://www2.census.gov/ces/opportunity/tract_outcomes_simple.csv
  - https://www2.census.gov/ces/opportunity/county_outcomes.zip
  - https://www2.census.gov/ces/opportunity/tract_outcomes.zip

Next lecture: Coding in R