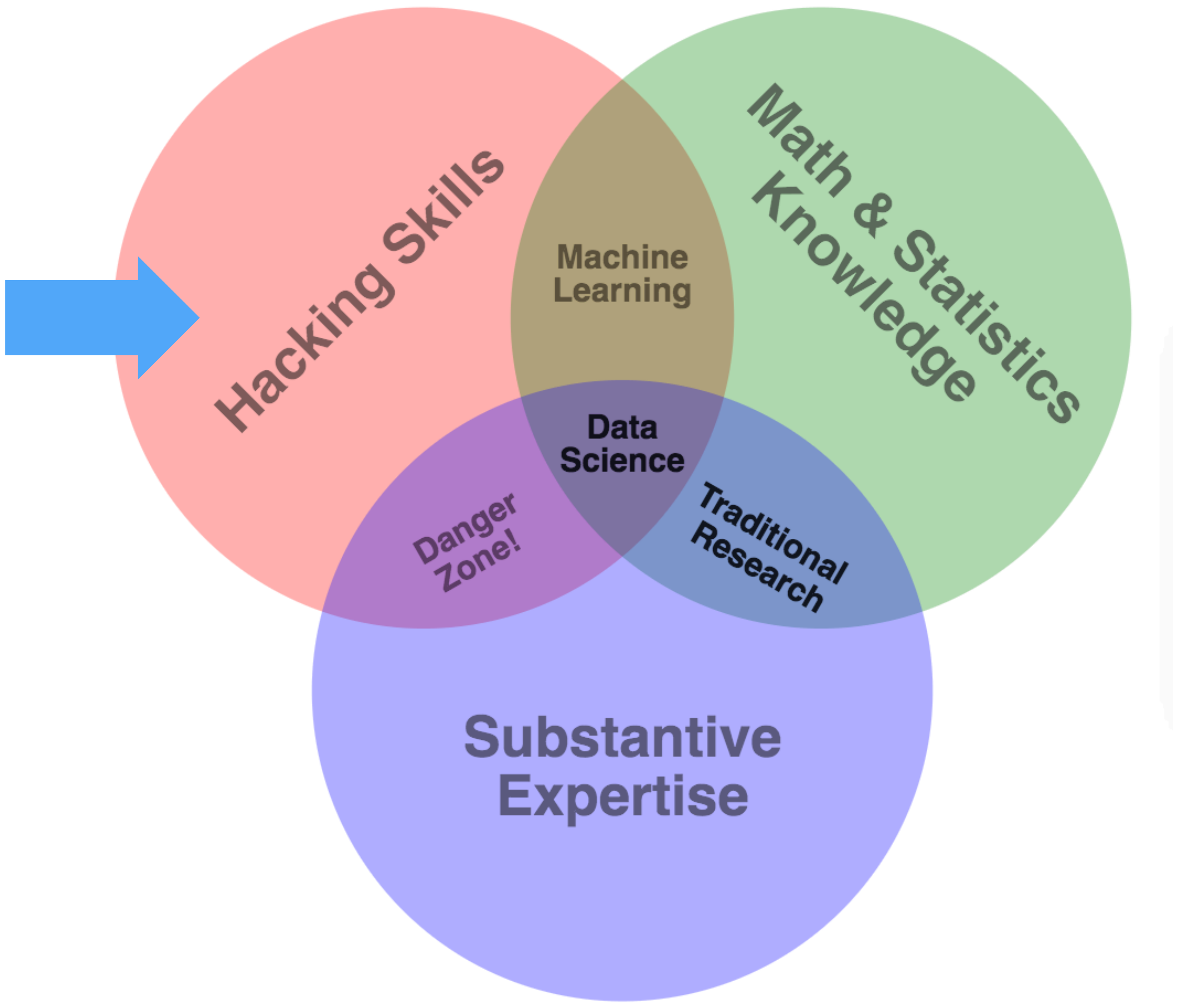
Lecture 4: Data Processing

COSC 480 Data Science, Spring 2017
Michael Hay

we are
still
here



Credit: https://s3.amazonaws.com/aws.drewconway.com/viz/venn_diagram/data_science.html

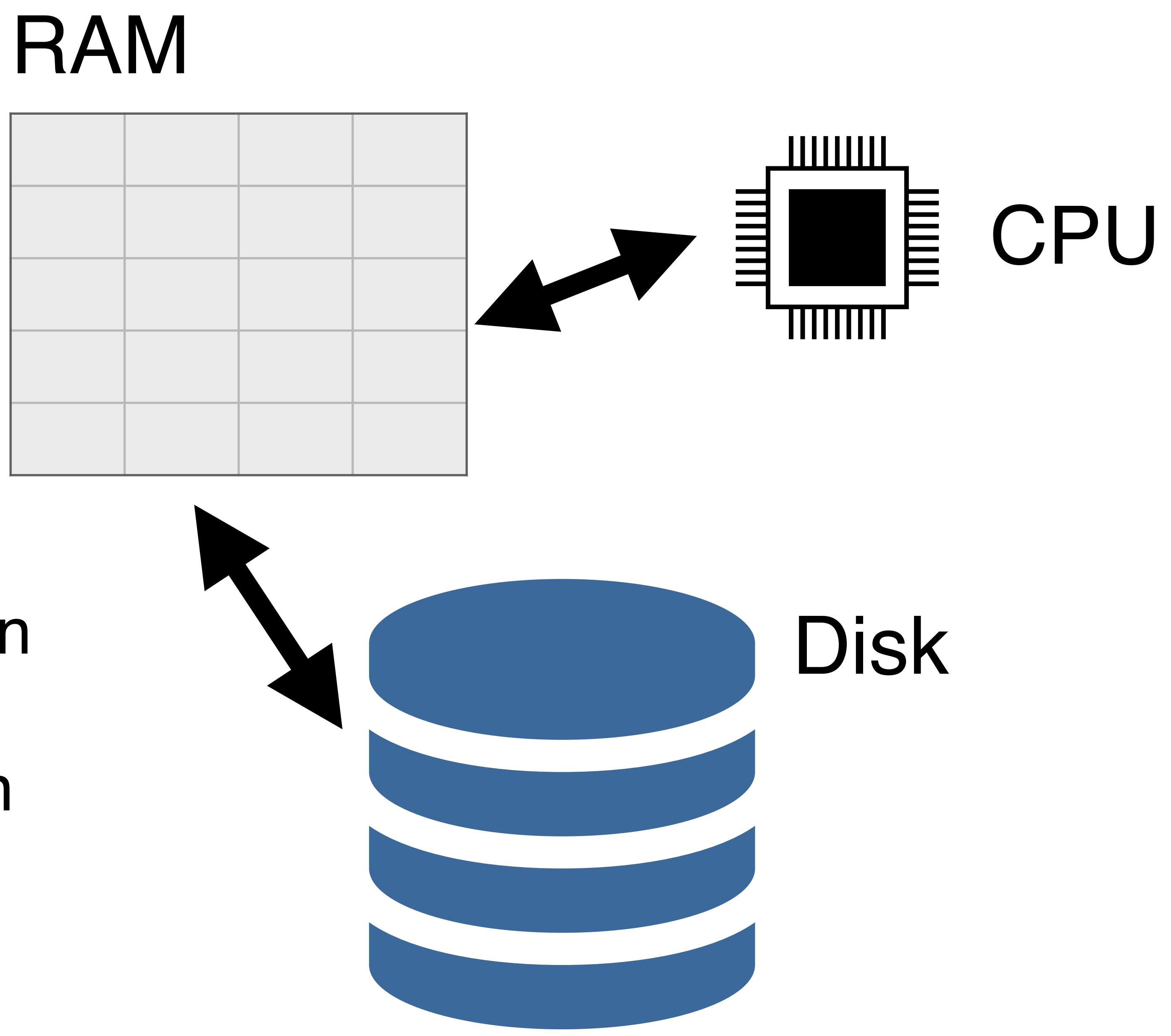
Goals for today

- Introduce some practical tools: unix utilities for working with large text files (e.g., a large CSV)
  - Useful for working with data directly, or for prepping data for storage in database
- Start to explore some of the practical/conceptual challenges that arise when working with "big" data
  - Specifically: "out of core" algorithms, rendezvous
- Motivate the desire for data manipulation tools (databases, python pandas)

Model of computation

(simplified Von Neuman Architecture)

1. Read something
2. Do something
3. Write something
4. Go to 1



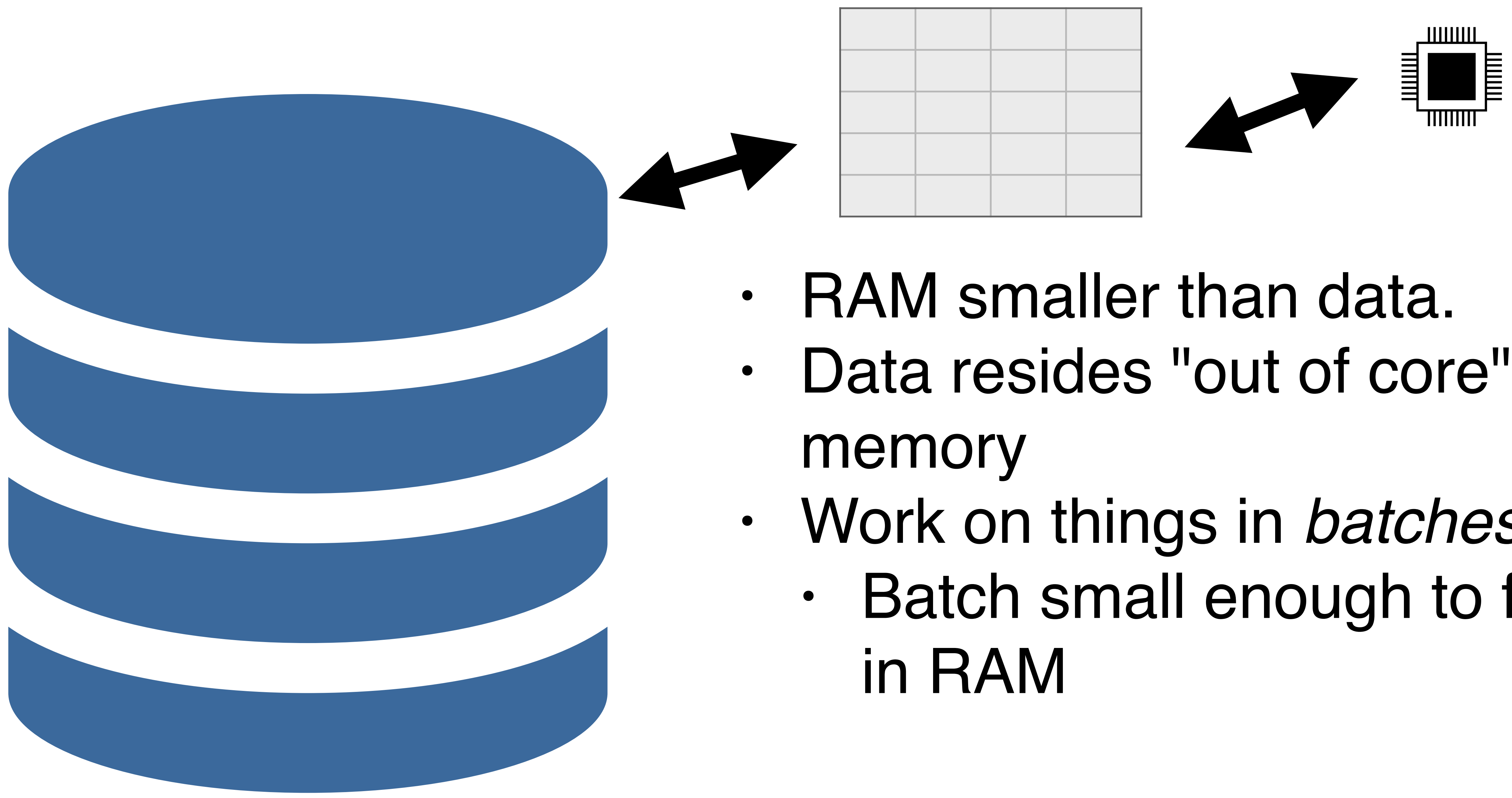
- Data moves between disk, RAM, CPU
- What happens when data is "big"?

processor by Prasad from the Noun Project

Degrees of Big

	M	L	XL	even bigger
Meaning	fits in RAM	fits on disk	multiple disks	storage cost exceeds budget
Approach	usual	out-of-core algorithms	parallel data	data streams
Practical	use whatever you want	use DB! (often requires some data prep)	use distributed DB!	clever approximation algorithms
	Python pandas, SQL database	SQL: postgresql, … NoSQL: mongodb, …	Hadoop ecosystem (includes map-reduce)	(later in semester: sampling, bloom filters, etc.)

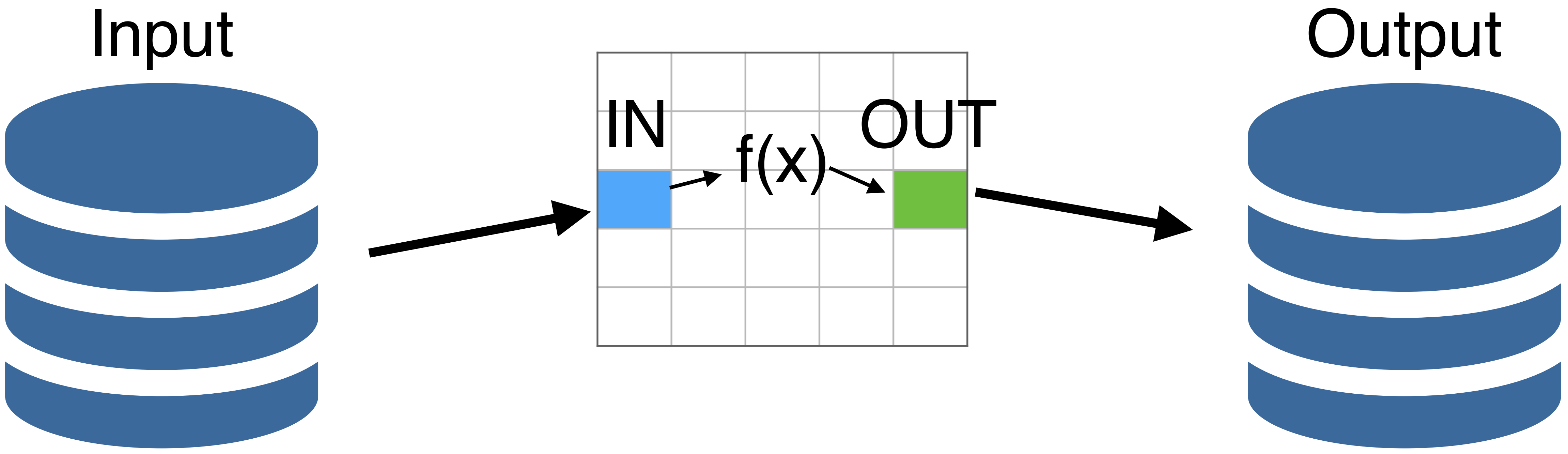
Out-of-core



- RAM smaller than data.
- Data resides "out of core" memory
- Work on things in *batches*
  - Batch small enough to fit in RAM

Streaming through RAM

- Simple case: map
    - Goal: Compute f(x) for each record, write out the result
    - Approach: read in a chunk from INPUT into IN *buffer*, do f(x) using available memory, write f(x) to OUT *buffer*
    - When IN buffer is empty, read another chunk; when OUT buffer is full, write to OUTPUT
- Reads and writes are *not* coordinated
    - Example: if *f(x)* is compress, then read many more than write
    - Example: if *f(x)* is uncompress, then write many more than read



Example

- Given a "large" text file containing "The Adventures of Sherlock Holmes," let's find & print proper nouns.
- Working definition of a proper noun: *a word that starts with capital letter*.
- Example: map1.py
- Ways to improve our proper noun detector?

Stream processing with UNIX utilities and pipes

- Several UNIX utilities for text processing — very useful in data cleaning/ wrangling!
- Text is treated as a stream of lines
- Streams: contents of a file, STDIN, STDOUT
- Connect with pipes |
    - OS will do chunking for you
- Example: "given csv file of student grades, find names of students who got at least one 100 and no zeros on assignments."

```
$ cat students.csv | grep ',100' | grep -v ',0' | cut -f 2 -d ','
```

Handy UNIX streaming utilities

- cat, head, tail, tee, cut, grep, split, sed, awk
- Handy tip: `tail -n+2 students.csv` skips csv header
- You can also mix unix utilities with python
  - Example map2.py

```
$ head small.txt | python map2.py | grep '^[A-Z][a-z]\+$'
```

Rendezvous

- Streaming: one chunk at a time. Easy.
- But… some algorithm need certain items to be co-resident in memory
  - Not guaranteed to appear in same input chunk
  - There may be many groups of such items
  - Example: building index of word occurrences
    ("Watson" appears on lines 1, 4, 10, …
    "Sherlock" appears on lines 1, 2, 6, 10, …)
- ***Time-space rendezvous***: data items meet in same place (RAM) at same time

Achieving rendezvous

- Two common building blocks: sorting and hashing
- **Sorting**
  - Choose sort order so that items that need to be co-resident are near each other in sort order
  - Out-of-core algorithm for sorting? (*Up next!*)

Key insight: complicated tasks can often be broken down into steps: stream, rendezvous (sort/hash), stream, rendezvous (sort/hash), …

- **Hashing**
  - Choose hash function so that items that need to be co-resident hash to same key
  - Out-of-core hashing? Recursive hashing (*Details omitted. Take cosc460!*)
  - **Aside**: if *set of keys is small* and only need to maintain *aggregation* of data items, then you may not need rendezvous but *accumulate* result in RAM.

Out-of-core sorting

- External merge sort (shown on the board)

Out-of-core sorting

- External merge sort (shown on the board)
- How do we merge chunks when each file is as large (or larger) than the available RAM?
  - See merge.py
  - Note: merge.py is not entirely correct. What's wrong?

Exercise

Instructions: ~1 minute to think/answer on your own; then discuss with neighbors; then I will call on one of you

- A *round* of merging corresponds to taking the current collection of chunk files and merging adjacent pairs.
- If we start with k chunk files, how many rounds of merging until we are done?
- If the input file has N units, and our RAM can hold B units, how many rounds of merging are required?
- Challenge: Can you think of any way to improve the algorithm and *lower* the number of rounds?

Instructions: ~1 minute to think/
answer on your own; then discuss with
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- If we start w
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- Challenge: (
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Solution:

- We start with k chunk files. How big is k? Well, it's ceiling(N / B) because we take our input file and break it up into B-sized chunks. We take the ceiling because the last chunk may be smaller than B.

- How many rounds? Each round takes the current number of files and merges pairs. Thus after one round, the number of files is cut in half. We repeat until we are down to one file. Thus, rounds = ceiling(log(k, 2)) where log(x, b) is logarithm of x base b.

- Improvement: merging two files only requires holding the "next" line of each file in memory. Thus, we can actually merge (roughly) B files simultaneously. This will make the rounds = ceiling(log(k, B)).

Handy UNIX r'vous utilities

- Non-streaming: **sort**, wc, tsort
- Stream rendezvous: uniq, join, paste, …
  - these require sorted input
- More information:
  - http://en.wikipedia.org/wiki/List_of_Unix_utilities
  - Sort on Category, search for "Text Processing"

Exercise

Instructions: ~2 minutes to think/answer on your own; then discuss with neighbors; then I will call on one of you

- Problem: Given a large text file, produce a list of the top 100 most frequent words in descending order
- How might you solve this problem?
  - Give a high level description of your approach.
  - Use sorting to achieve rendezvous.

Exerci

- Problem: G
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  - Use sorti

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Solution:

- stream lines of file, split into words, writing out one word per line into a file.
- sort word file. now all occurrences of a word appear together. think of these as "word groups"
- initialize an empty list of the top 100 words. stream lines of word file.
  - initialize a counter to zero. as long as current word equals previously seen word, we are still in the same "word group", so increment counter;
  - when current word differs from previous word, we know we're starting a new "word group" and we've finished counting occurrences of the previous word. so compare its counter with top 100 word counts. if this counter is larger than the smallest counter in the top 100, keep it and discard the smallest from top 100.

Exercise

Instructions: ~2 minutes to think/ answer on your own; then discuss with neighbors; then I will call on one of you

- Problem: Given the logs of an Internet Service Provider (ISP) of the form

```
ip,url,datetime,...
127.0.0.1, 'https://www.nytimes.com/2016/06/26/...', 2016-11-30 8:00,...
127.0.0.1, 'http://www.espn.com/nfl/team/_/name/ne/', 2016-11-30 8:12,...
127.0.0.3, 'http://www.espn.com/nfl/index?tab=2', 2016-11-30 8:14,...
127.0.0.3, 'http://www.cnn.com/election/results', 2016-11-30 8:14,...
127.0.0.3, 'http://www.cnn.com/main', 2016-11-30 8:15,...
127.0.0.1, 'https://www.nytimes.com/section/science', 2016-11-30 8:19,...
127.0.0.1, 'https://xkcd.com/1792/', 2016-11-30 8:29,...
...
```

- Find sites (e.g., nytimes.com) that have at least *k* pages each getting at least *m* visits. Use sorting to r'vous.

- Challenge: how would your answer change if it was *m* distinct *visitors* (determined by ip address)?

Instructions: ~2 minutes to think/

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Exerci

- Problem: Giv
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```
ip,url,datetime
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127.0.0.3, 'htt
127.0.0.1, 'htt
127.0.0.1, 'htt
...
```

- Find sites (e
each getting

- Challenge: h
distinct *visito*

Solution:

- sort file by url
- for each url, count number of visits (similar to how we counted words in previous example). when we reach end of current url "group", if the count is >= m, then extract the site from the url (use a regular expression) and write the site to a line in a new file of sites.
- sort the site file*
- for each site, count number of occurrences (similar to how we counted word). if the count >= k, then print the site.

* this is not really necessary since the site is the first part of the url, so the stream of sorted urls is already sorted by site.

Summary

- "Out of core" algorithms: when data size exceeds memory size
- Streaming: a simple out of core algorithm, process data as it streams through main memory
- Streaming not always enough: must solve the *rendezvous* problem. Common approaches:
    - Sort: choose sort order so related items are near each other in sort order
    - Hashing: choose hash function so that related items hash to same key
- Many complex analysis tasks can often be decomposed by interleaving streaming with hashing/sorting