CompSci 101
Introduction to Computer Science

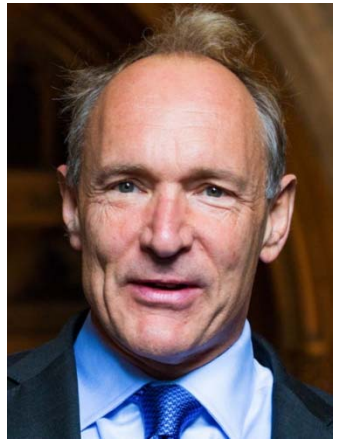
Nov 21, 2017

Prof. Rodger

```
[("ant",5),("bat", 4),("cat",5),("dog",4)]
[("ant",5),("cat", 5),("bat",4),("dog",4)]
```

Inventor of World Wide Web Receives ACM A.M. Turing Award

Sir Tim Berners-Lee Designed Integrated Architecture and Technologies that Underpin the Web



ACM named Sir Tim Berners-Lee, a Professor at Massachusetts Institute of Technology and the University of Oxford, the recipient of the 2016 ACM A.M. Turing Award. Berners-Lee was cited for inventing the World Wide Web, the first web browser, and the fundamental protocols and algorithms allowing the Web to scale. Considered one of the most influential computing innovations in

Announcements

- Exam 2 back after break
- Assignment 8 out soon due Dec 5
- APT 8 out soon and due Dec 7
  - Doing extra ones – good practice for final

- Today:
  - Dictionary timings
  - Efficiency
  - Sorting

DifferentTimings.py Problem:

- Start with a large file, a book, hawthorne.txt
- For each word, count how many times the word appears in the file
- Create a list of tuples, for each word:
  - Create a tuple (word, count of word)
- We will look at several different solutions

DifferentTimings.py
Problem: (word,count of word)

- Updating (key,value) pairs in structures
- Three different ways:
  1. Search through unordered list
  2. Search through ordered list
  3. Use dictionary
- Why is searching through ordered list fast?
  - Guess a number from 1 to 1000, first guess?
  - What is 2^{10}? Why is this relevant? 2^{20}?
  - Dictionary is faster! But not ordered

Linear search through list o' lists

- Maintain list of [string,count] pairs
  - List of lists, why can't we have list of tuples?

[['dog', 2], ['cat', 1], ['bug', 4], ['ant', 5]]

  - If we read string 'cat', search and update

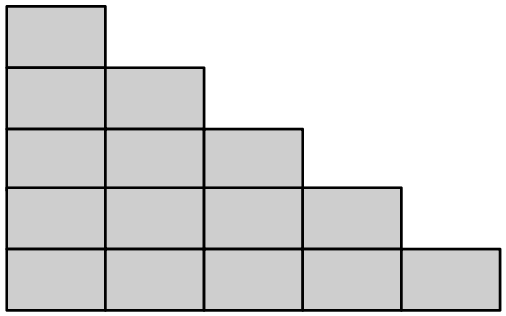
[['dog', 2], ['cat', 2], ['bug', 4], ['ant', 5]]

  - If we read string 'frog', search and update

[['dog', 2],['cat', 2],['bug', 4],['ant', 5],['frog',1]]

See DifferentTimings.py

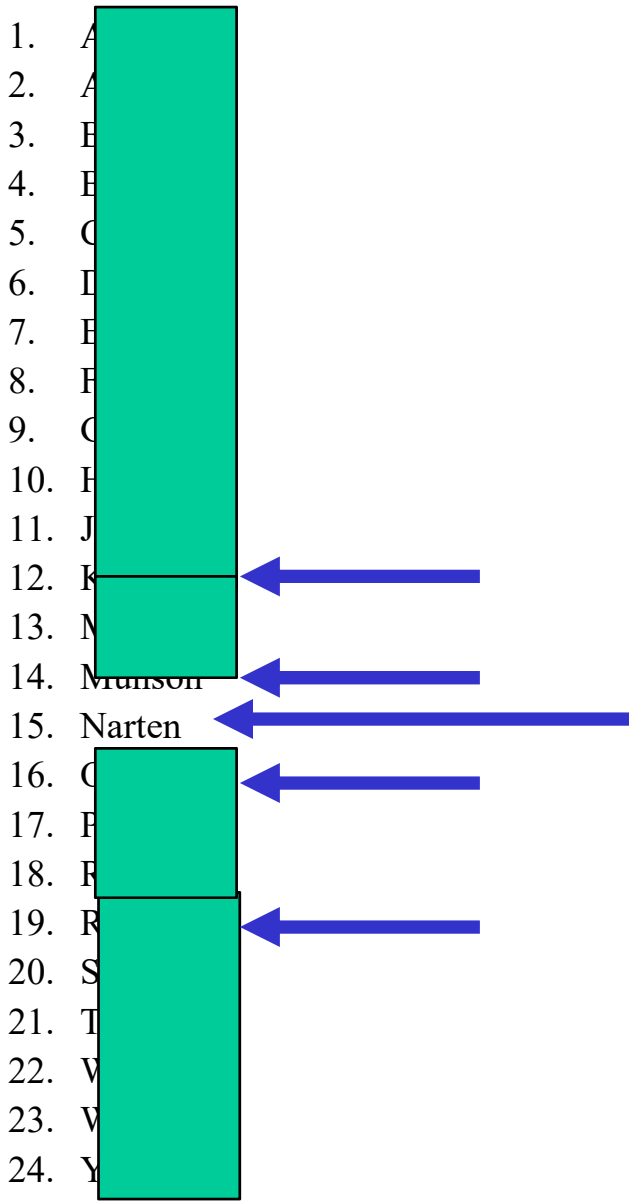
```
def linear(words):
    data = []
    for w in words:
        found = False
        for elt in data:
            if elt[0] == w:
                elt[1] += 1
                found = True
                break
        if not found:
            data.append([w,1])
    return data
```



N new words?

Binary Search

Find Narten



FOUND!

How many times divide in half?

$\log_2(N)$ for N element list

Binary search through list o' lists

- Maintain list of [string,count] pairs **in order**

[[‘ant', 4], [‘frog', 2]]

– If we read string 'cat', search and update

[[‘ant', 4], [‘cat’, 1], [‘frog', 2]]

– If we read string ‘dog‘ twice, search and update

[[‘ant', 4], [‘cat’, 1], [‘dog’, 1], [‘frog', 2]]

[[‘ant', 4], [‘cat’, 1], [‘dog’, 2], [‘frog', 2]]

See DifferentTimings.py
bit.ly/101f17-1121-1

```
def binary(words):
    data = []
    for w in words:
        elt = [w,1]
        index = bisect.bisect_left(data, elt)
        if index == len(data):
            data.append(elt)
        elif data[index][0] != w:
            data.insert(index,elt)
        else:
            data[index][1] += 1
    return data
```

Search via Dictionary

- In linear search we looked through all pairs
- In binary search we looked at log pairs
  - But have to shift lots if new element!!
- In dictionary search we look at one pair
  - Compare: one billion, 30, 1, for example
  - Note that $2^{10} = 1024$, 2^{20} = million, 2^{30}=billion

- Dictionary converts key to number, finds it
  - Need far more locations than keys
  - Lots of details to get good performance

See DifferentTimings.py

```
def dictionary(words):
    d = {}
    for w in words:
        if w not in d:
            d[w] = 1
        else:
            d[w] += 1
    return [[w,d[w]] for w in d]
```

Running times @ 10^9 instructions/sec

	Dictionary	List sorted	List unordered
N	*O(log N)*	*O(N)*	*O(N log N)*	*O(N^2)*
10^2	`0.0`	`0.0`	`0.0`	`0.00001`
10^3				
10^6				
10^9				
10^{12}				

This is a real focus in Compsci 201

linear is N^2, binary search is N log N, dictionary N

What's the best and worst case? Bit.ly/101f17-1121-2

- If every word is the same ….
  - Does linear differ from dictionary? Why?
- If every word is different in alphabetical order…
  - Does binary differ from linear? Why?
- When would dictionary be bad?

Problem Solving with Algorithms

- Top 100 songs of all time, top 2 artists?
  - Most songs in top 100
  - Wrong answers heavily penalized
  - You did this in lab, you could do this with a spreadsheet

- What about top 1,000 songs, top 10 artists?
  - How is this problem the same?
  - How is this problem different

Scale

- As the size of the problem grows …
  - The algorithm continues to work
  - A new algorithm is needed
  - New engineering for old algorithm

- Search
  - Making Google search results work
  - Making SoundHound search results work
  - Making Content ID work on YouTube

Python to the rescue?
Top1000.py

```
import csv, operator

f = open('top1000.csv','rbU')
data = {}
for d in csv.reader(f,delimiter=',',quotechar='"'):
    artist = d[2]
    song = d[1]
    if not artist in data:
        data[artist] = 0
    data[artist] += 1

itemlist = data.items()
dds = sorted(itemlist,key=operator.itemgetter(1),reverse=True)
print dds[:30]
```

Understanding sorting API

- How API works for `sorted()` or `.sort()`
  - Alternative to changing order in tuples and then changing back

```
x = sorted([(t[1],t[0]) for t in dict.items()])
x = [(t[1],t[0]) for t in x]

x = sorted(dict.items(),key=operator.itemgetter(1))
```

- Sorted argument is key to be sorted on, specify which element of tuple. Must import library operator for this

Sorting from an API/Client perspective

- API is Application Programming Interface, what is this for sorted(..) and .sort() in Python?
  - Sorting algorithm is efficient, stable: part of API?
  - `sorted` returns a list, doesn't change argument
  - `sorted(list,reverse=True)`, part of API
  - `foo.sort()` modifies foo, same algorithm, API

- How can you change how sorting works?
  - Change order in tuples being sorted,
    - `[(t[1],t[0]) for t in …]`
  - Alternatively: `key=operator.itemgetter(1)`

Beyond the API, how do you sort?

- Beyond the API, how do you sort in practice?
  - Leveraging the stable part of API specification?
  - If you want to sort by number first, largest first, breaking ties alphabetically, how can you do that?
- Idiom:
  - Sort by two criteria: use a two-pass sort, first is secondary criteria (e.g., break ties)

```
[("ant",5),("bat", 4),("cat",5),("dog",4)]
[("ant",5),("cat", 5),("bat",4),("dog",4)]
```

Two-pass (or more) sorting

- Because sort is stable sort first on tie-breaker, then that order is fixed since stable

```
a0 = sorted(data,key=operator.itemgetter(0))
a1 = sorted(a0,key=operator.itemgetter(2))
a2 = sorted(a1,key=operator.itemgetter(1))
data
[('f', 2, 0), ('c', 2, 5), ('b', 3, 0),
 ('e', 1, 4), ('a', 2, 0), ('d', 2, 4)]
a0
[('a', 2, 0), ('b', 3, 0), ('c', 2, 5),
 ('d', 2, 4), ('e', 1, 4), ('f', 2, 0)]
```

Two-pass (or more) sorting

```
a0 = sorted(data,key=operator.itemgetter(0))
a1 = sorted(a0,key=operator.itemgetter(2))
a2 = sorted(a1,key=operator.itemgetter(1))
a0
[('a', 2, 0), ('b', 3, 0), ('c', 2, 5),
 ('d', 2, 4), ('e', 1, 4), ('f', 2, 0)]
a1
[('a', 2, 0), ('b', 3, 0), ('f', 2, 0),
 ('d', 2, 4), ('e', 1, 4), ('c', 2, 5)]
a2
[('e', 1, 4), ('a', 2, 0), ('f', 2, 0),
 ('d', 2, 4), ('c', 2, 5), ('b', 3, 0)]
```

How to import: in general and sorting

- We can write: import operator
  - Then use key=operator.itemgetter(…)

- We can write: from operator import itemgetter
  - Then use key=itemgetter(…)

Sorting
www.bit.ly/101f17-1121-3