CompSci 101
Introduction to Computer Science

Key	Value
"O _ O _"	"OBOE", "ODOR"
"_ O O _"	"NOON", "ROOM", "HOOP"
" _ O _O"	"SOLO" "GOTO"
"_ _ _ O"	"TRIO"
"O _ _ _"	"OATH", "OXEN"
"_ _ _ _"	"PICK", "FRAT"

November 10, 2016

Prof. Rodger

Announcements

- Assign 6 due extended one day
  - Assign 7 out today, due Nov 29
- APT 9 due Tuesday (No extensions)
- Next week – No lab, Exam Thursday
- Practice exams – work on for next class

- Today:
  - Why are dictionaries so fast?
  - More problem solving with dictionaries

Be in the know….
ACM, compsci mailing lists

- Association of Computing Machinery (ACM)
  - Professional organization for computer science
  - Duke Student ACM Chapter – join for free
- Join duke email lists to find out info on jobs, events for compsci students
  - lists.duke.edu – join lists:
    - compsci – info from compsci dept
    - dukeacm – info from student chapter

Dictionary Song problem
bit.ly/101f16-1110-1

songs = [*"Hey Jude:Let it be:Day Tripper",*
"Let it be:Drive my car:Hey Jude",
"I want to hold your hand:Day Tripper:Help!",
"Born to run:Thunder road:She's the one",
"Hungry heart:The river:Born to run",
"The river:Thunder road:Drive my car",
"Angie:Start me up:Ruby Tuesday",
"Born to run:Angie:Drive my car"]

APT EmailsCourse
bit.ly/101f16-1110-2

You are given a list of strings of course information, where each string is in the format "coursename:person:email". Your task is to determine the course with the most people and to return the emails of those people in the largest course. The emails should be returned as a string with the emails in alphabetical order. If there is more than one largest course, return the emails of such course that comes first in alphabetical order.

```
["CompSci 100:Fred Jack Smith:fjs@duke.edu",
  "History 117:Fred Jack Smith:fjs@duke.edu",
  "CompSci 102:Arielle Marie Johnson:amj@duke.edu",
  "CompSci 100:Arielle Marie Johnson:amj@duke.edu",
  "CompSci 006:Bertha White:bw@duke.edu",
  "Econ 051:Bertha White:bw@duke.edu",
  "English 112:Harry Potter:hp@duke.edu",
  "CompSci 100:Harry Potter:hp@duke.edu"]

Returns "amj@duke.edu fjs@duke.edu hp@duke.edu"
```


DictionaryTimings.py
Problem: (word,count of words)

- 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

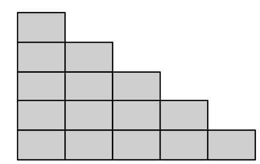
[['dog', 2], ['cat', 2], ['bug', 4], ['ant', 5]]

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

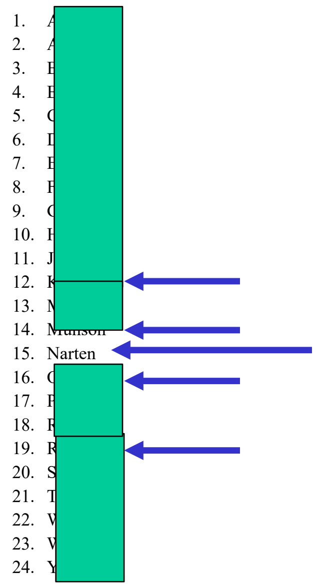
[['dog', 2],['cat', 2],['bug', 4],['ant', 5],['frog',1]]

See DictionaryTimings.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 DictionaryTimings.py bit.ly/101f16-1110-3

```
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 DictionaryTimings.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

N	*O(log N)*	*O(N)*	*O(N log N)*	*O(N²)*
10^2	0.0	0.0	0.0	0.00001
10^3	0.0	0.0000001	0.00001	
10^6	0.0	0.001	0.02	
10^9	0.0	1.0	29.9	
10^{12}	9.9 secs	16.7 min	11.07 hr	

This is a real focus in Compsci 201

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

What's the best and worst case? Bit.ly/101f16-1110-4

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

Next Assignment –

Clever, Snarky, Evil, Frustrating Hangman

- Computer changes secret word every time player guesses to make it "hard" to guess
  - Must be consistent with all previous guesses
  - Idea: the more words there are, harder it is
    - Not always true!
- Example of greedy algorithm
  - Locally optimal decision leads to best solution
  - More words to choose from means more likely to be hung

Canonical Greedy Algorithm

- How do you give change with fewest number of coins?
  - Pay $1.00 for something that costs $0.43
  - Pick the largest coin you need, repeat

Greedy not always optimal

- What if you have no nickels?
  - Give $0.31 in change
  - Algorithms exist for this problem too, not greedy!

Clever Hangman

- When you guess a letter, you're really guessing a category (secret word "salty")

_ _ _ _ _ and user guesses 'a'

  - "gates", "cakes", "false" are all *the same*
  - "flats", "aorta", "straw", "spoon" are all *different*

- How can we help ensure player always has many words to distinguish between?

Debugging Output

number of misses left: 8
secret so far: _ _ _ _ _ _ _ _
(word is catalyst)
 # possible words: 7070
guess a letter: a
a__a___a 1
…
_a______ 587
__aa____ 1
…
__a_____ 498
________ 3475
___a____ 406
…
____a___ 396
 # keys = 48

number of misses left: 7
letters not yet guessed:
bcdefghijklmnopqrstuvwxyz
…
(word is designed)
 # possible words: 3475
guess a letter:

Debugging Output and Game Play

- Sometimes we want to see debugging output, and sometimes we don't
  - While using microsoft word, don't want to see the programmer's debugging statements
  - Release code and development code
- You'll approximate release/development using a global variable DEBUG
  - Initialize to False, set to True when debugging
  - Ship with DEBUG = False

Look at howto and categorizing words

- Play a game with a list of possible words
  - Initially this is all words
  - List of possible words changes after each guess
- Given template "_ _ _ _", list of all words, and a letter, choose a secret word
  - Choose all equivalent secret words, not just one
  - Greedy algorithm, choose largest category

Computing the Categories

- Loop over every string in words, each of which is consistent with guess (template)
  - This is important, also letter *cannot* be in guess
  - Put letter in template according to word
  - _ _ _ a _ t might become _ _ _ a n t
- Build a dictionary of templates with that letter to all words that fit in that template.
- How to create key in dictionary?

Dictionary to help solve…

- Example: Four letter word, guess o

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"O _ O _"	"OBOE", "ODOR"
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- Key is string, value is list of strings that fit

Keys can't be lists

- [“O”,”_”,”O”,”_”] need to convert to a string to be the key representing this list:

  “O_O_”