



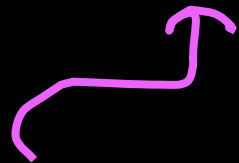
Data Structures

Chris Piech
CS106A, Stanford University

If I only had one
variable type..

It would be a `HashMap`

HashMap
key -> value



Can be any type

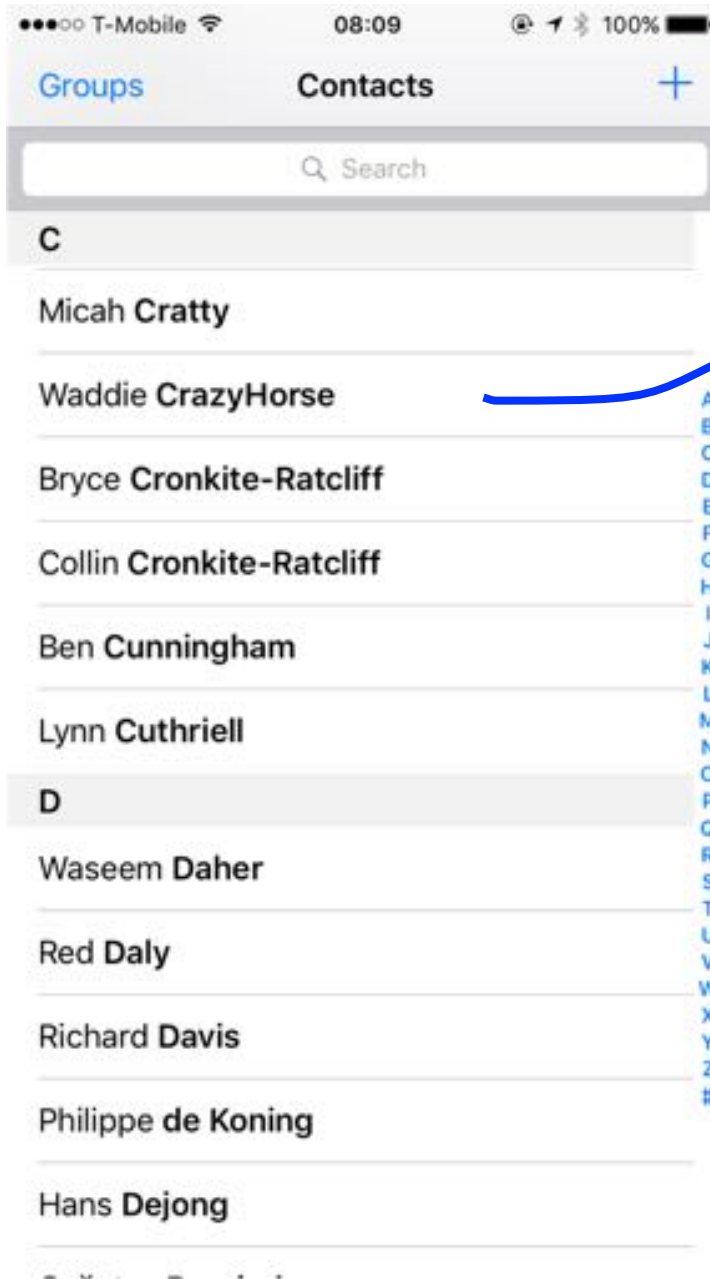
HashMap



A HashMap is a collection which allows you to look up **values** based on **keys**.



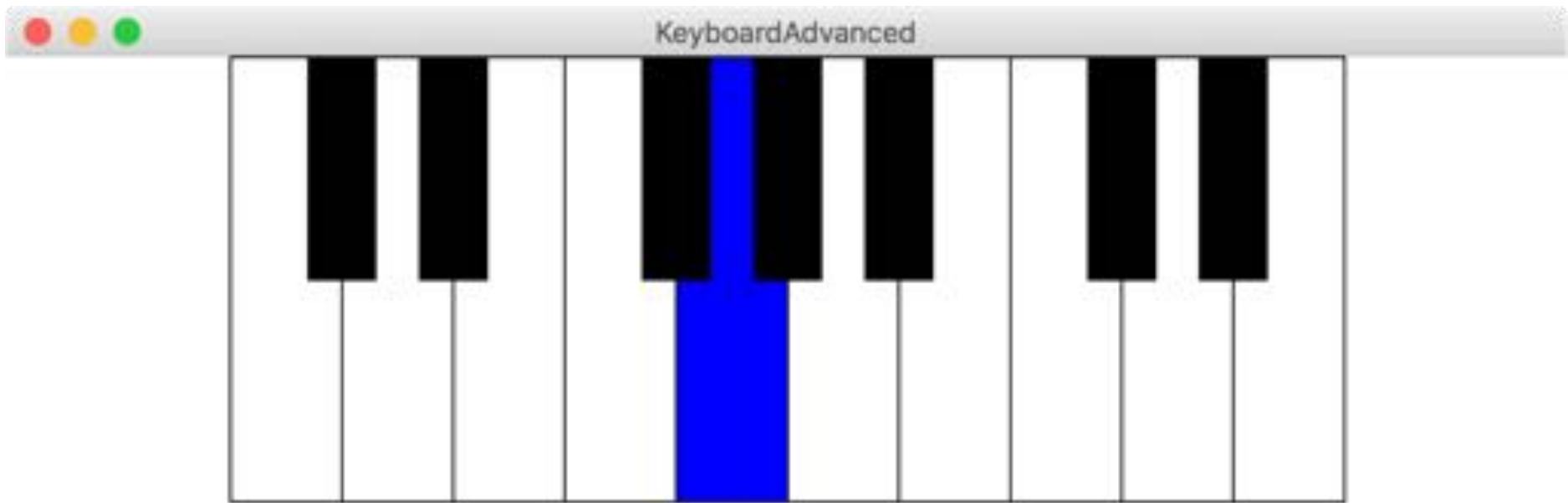
Name (String) -> Number (Integer)



6701678



Keys (Grect) -> Sound (AudioFile)



Collections in CS106A



Aka Data Structures

- **Arrays**
- **Indexed** list. **Fixed** size.
- **ArrayLists**
- **Indexed** list. **Changes** size.
- **Matrices**
- **Indexed** array of arrays. **Fixed** size.
- **HashMaps**
- Lookup Values by **Keys**. **Changes** size

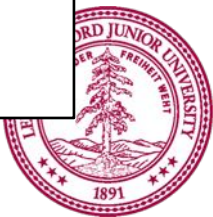
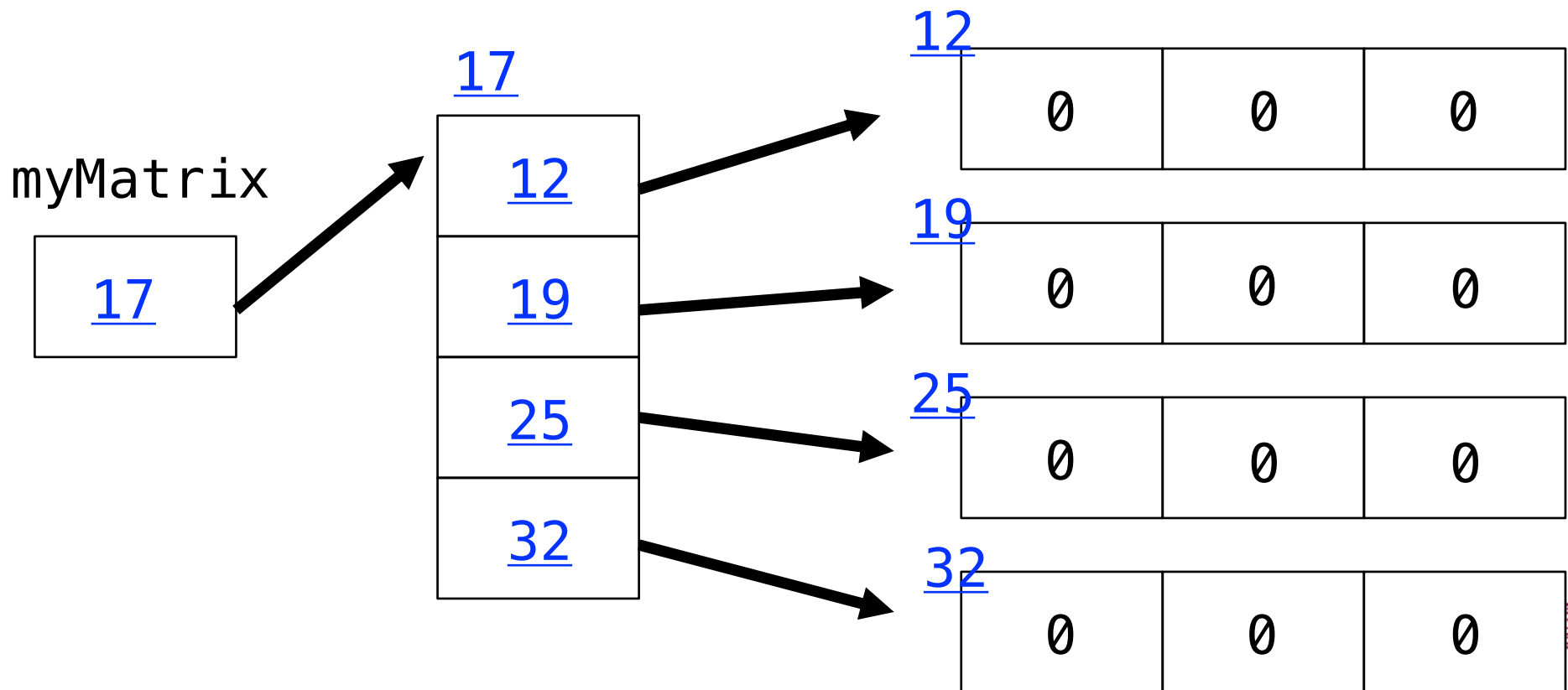


Aside: All collections are Objects



Collection variables store addresses. Manage memory well.

```
int[][] myMatrix = new int[5][3]
```



End Review

Why is this so fast?



mantis shrimp colors



All

Videos

Shopping

Images

News

More

Settings

Tools

About 1,870,000 results (0.54 seconds)

Humans and many other primates have three; some birds and reptiles have four photoreceptors. Certain butterflies can even have six. But the mantis shrimp has 12 different types of photoreceptors in their eyes – and scientists haven't understood why until now. Jan 27, 2014



Study Offers Insights into Unique Color Vision of Mantis Shrimp ...

www.sci-news.com/biology/science-color-vision-mantis-shrimp-01719.html



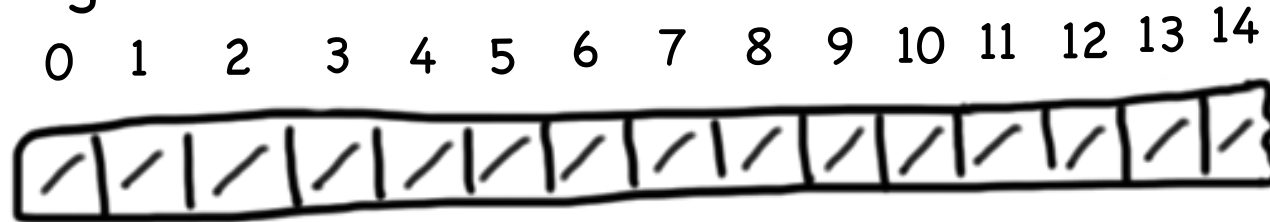
The internet is big

5 million articles and growing

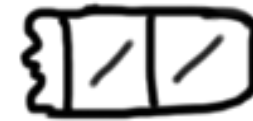


Why is this so fast?

Google search:



999,999,999



```
int hashFn(String key);
```

* Learn more in CS106B



A Basic Hash Function

```
int basicStringHash(String key) {  
    int preHash = 0;  
    for(int i = 0; i < key.length(); i++){  
        preHash += key.charAt(i);  
    }  
    return preHash % NUM_BUCKETS;  
}
```

* Learn more in CS106B



Why is this so fast?



Any HashMap action is a **two step** process. **Regardless** of how much data is in the HashMap



mantis shrimp colors



All

Videos

Shopping

Images

News

More

Settings

Tools

About 1,870,000 results (0.54 seconds)

Humans and many other primates have three; some birds and reptiles have four photoreceptors. Certain butterflies can even have six. But the mantis shrimp has 12 different types of photoreceptors in their eyes – and scientists haven't understood why until now. Jan 27, 2014



Study Offers Insights into Unique Color Vision of Mantis Shrimp ...

www.sci-news.com/biology/science-color-vision-mantis-shrimp-01719.html

HashMaps for search



Google Search

Key

word

“Shrimp”



Value

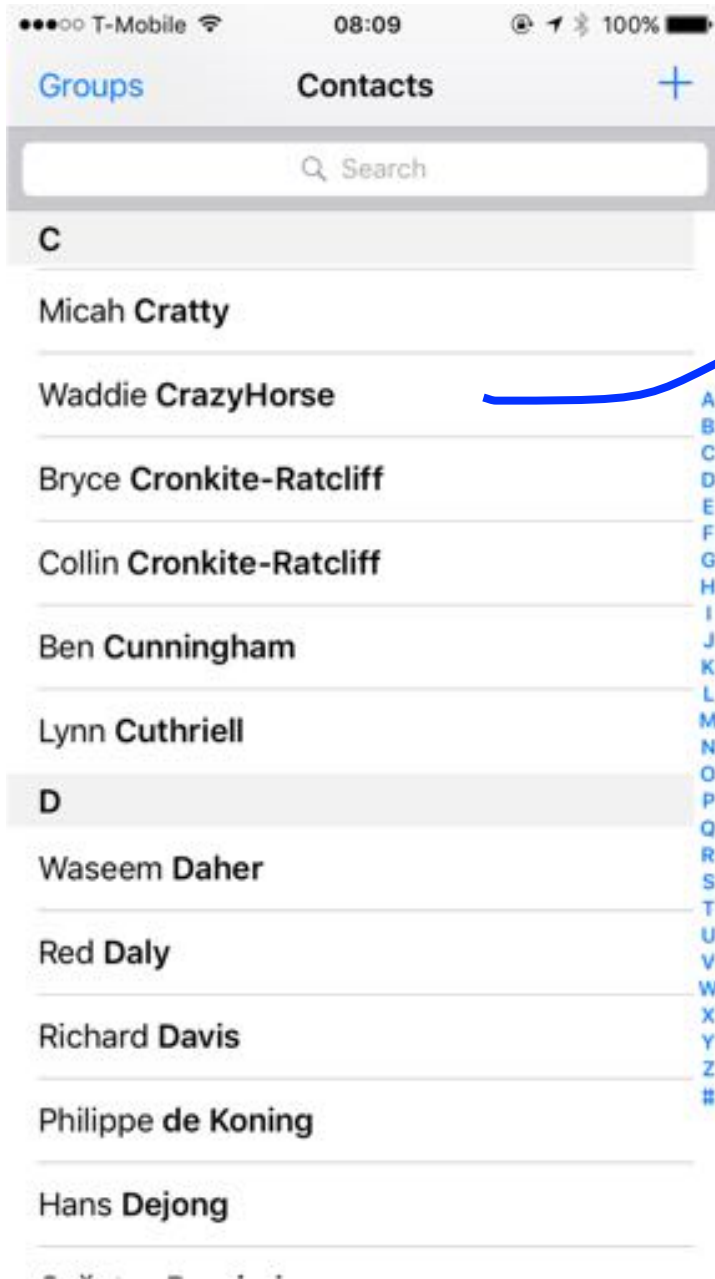
All websites
with that
word

[
“Wikipedia.com/...”,
“Allrecipes.com/...”,
...
]



Single Key with
multiple Values?

Learn by Experimenting

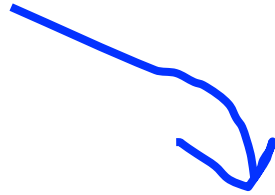


6701678

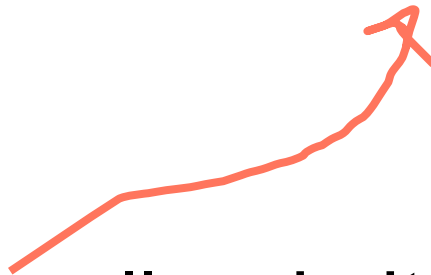


Google Search

Key: search words



HashMap<**String**, **ArrayList<String>**>



Value: all websites with that word



HashMaps

ArrayLists

Arrays



mix 'em together



the possibilities are endless!



Public View of Stanford People X +

https://stanfordwho.stanford.edu/SWApp/

STANFORD UNIVERSITY | SEARCHING STANFORD

Stanford Web | **People** | Organizations | Campus Map

Stanford Hospital: Find a Physician | LPCH: Find a Doctor

The public view of StanfordWho will soon have a new display and features. [Learn more.](#)

Search by name, email, work phone, or sunsetid | [Search in Stanford and Affiliates view >>](#) | guest | login

Search

[show more options](#)

Stanford Home | Re-Authenticate | Help/SU | Help with StanfordWho

© Stanford University, 450 Serra Mall, Stanford, California 94305-5080 | 723-2300 | [Terms of Use](#) | [Copyright](#) | [Complaints](#)



Public View of Stanford People X

https://stanfordwho.stanford.edu/SWApp/

STANFORD UNIVERSITY

SEARCHING STANFORD

Stanford Web | **People** | Organizations | Campus Map

Stanford Hospital: Find a Physician | LPCH: Find a Doctor

The public view of StanfordWho will soon have a new display and features. [Learn more.](#)

Search by name, email, work phone, or sunsetid

Search in Stanford and Affiliates view >>

guest | login

maya

show more results

Search

Stanford Home | Re-Authenticate | Help/SU | Help with StanfordWho

© Stanford University, 450 Serra Mall, Stanford, California 94305. (650) 723-2300. [Terms of Use](#) | [Copyright](#) | [Complaints](#)



Public Results from Stanford | X +

https://stanfordwho.stanford.edu/SWApp/Search.do

STANFORD UNIVERSITY | SEARCHING STANFORD

Stanford Web | People | Organizations | Campus Map

Stanford Hospital: Find a Physician | LPCH: Find a Doctor

The public view of StanfordWho will soon have a new display and features. [Learn more.](#)

Search by name, email, work phone, or sunsetid | [Search in Stanford and Affiliates view >>](#) | [guest](#) | [login](#)

maya |

[show more options](#)

43 results

Maya Adam	Lecturer in Pediatrics - Infectious Diseases	(University - Academic staff)
Maya Anne Criaencia Dodson	Undergraduate in Vice Provost for Undergraduate Education	(University - Student)
Maya Acad	No information available	
Maya Arce	Life Science Research Professional 1 in Biochemistry - Genome Center	(University - Staff)
Maya Balamane	No information available	
Maya Beeler	Graduate, Law in Law School	(University - Student)
Maya Berdichesky	Clinical Trials Reg Mgr in Med/Stanford Center for Clinical Research	(University - Staff)
Maya Boutros	Graduate, Business in Graduate School of Business	(University - Student)
Maya Brandt Mathur	Casual - Non-Exempt in Med/Quantitative Sciences Unit Med/Quantitative Sciences Unit	(University - Staff, Affiliate)



Section Leader Who



Chris Piech
(cpiech)



Gaby Candes
(gcandes)



Brahm Capoor
(bcapoor)



Andrew Tierno
(atierno)



Maya Ziv
(mziv)



Christian Davis
(cdavis)



Section Leader Who

```
StanfordWhoSoln
Stanford Who
? Chris
Results:
Chris Collins (ccollins)
Chris Koenig (ckoenig)
Chris Piech (cpiech)
Chris Wang (cwang)

? Capoor
Results:
Brahm Capoor (bcapoor)

? Maya
Results:
Maya Balakrishnan (mbalakrishnan)
Maya Israni (misrani)
Maya Ziv (mziv)

? mziv
Results:
Maya Ziv (mziv)

?
```

The user enters a query

You give the results



Section Leader Who



```
1 Aamnah Khalid (akhalid)
2 Aaron Broder (abroder)
3 Abraham Starosta (astarosta)
4 Adam Abdulhamid (aabdulhamid)
5 Adam Ginzberg (aginzberg)
6 Adam Mosharrafa (amosharrafa)
7 Adi Chander (achander)
8 Aditya Bhandari (abhandari)
9 Aditya Dev Gupta (adev)
10 Ajay Sohmshetty (asohmshetty)
11 Akshay Agrawal (aagrawal)
12 Akua McLeod (amcleod)
13 Aleksander Dash (adash)
14 Alena Rott (springheart)
15 Alex Bucquet (abucquet)
16 Alex Haigh (summerearth9)
17 Alex Mallery (amallery)
18 Alex Valderrama (avalderrama)
19 Alexander Carlisle (acarlisle)
20 Alexander De Baets (ade)
21 Alfred Zong (azong)
22 Ali Fauci (smallfrog)
23 Ali Malik (amalik)
24 Alice Hau (spacewave)
25 Allison Tielking (summerge)
26 Alisha Adam (springsky)
27 Allison Tielking (summerge)
28 Alona King (aking)
29 Alyssa Vann (avann)
30 Ambika Acharya (aacharya)
31 Amit Schechter (aschechter)
32 Amy Nguyen (topwave)
```

sls.txt:

Has all section leaders in history, one per line.

Example Name:

Alisha Adam (springsky)



Section Leader Who

```
/* Print Query Responses
 * -----
 * Print all students who have the query as either
 * their sunetId or as one of their names
 * Example queries:
 * "Chris", "Capoor", "Maya", "mziv"
 */
private void printQueryResponses(String query) {

    // TODO: your code here

}
```



Approach #1: Needle in Haystack

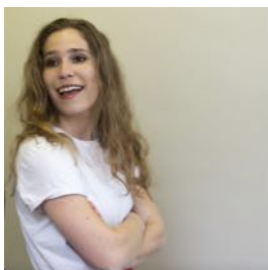
Query: "Davis"



Chris
Piech
cpiech



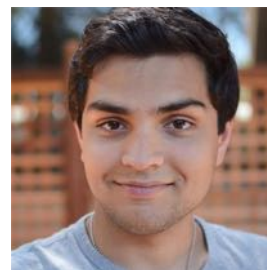
Brahm
Capoor
bcapoor



Maya
Ziv
mziv



Gaby
Candes
gcandes



Andrew
Tierno
atierno



Christian
Davis
cdavis



Approach #1: Needle in Haystack

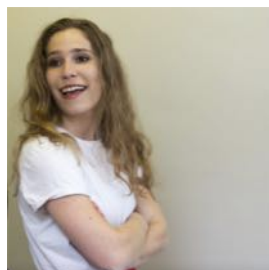
Query: "Davis"



Chris
Piech
cpiech



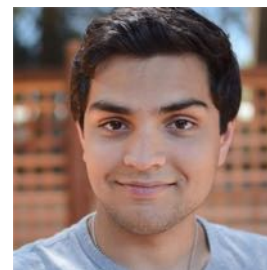
Brahm
Capoor
bcapoor



Maya
Ziv
mziv



Gaby
Candes
gcandes



Andrew
Tierno
atierno



Christian
Davis
cdavis



Approach #1: Needle in Haystack

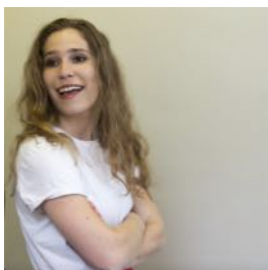
Query: "Davis"



Chris
Piech
cpiech



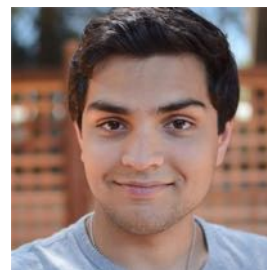
Brahm
Capoor
bcaoor



Maya
Ziv
mziv



Gaby
Candes
gcandes



Andrew
Tierno
atierno



Christian
Davis
cdavis



Approach #1: Needle in Haystack

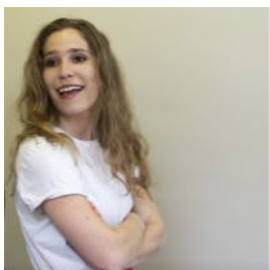
Query: "Davis"



Chris
Piech
cpiech



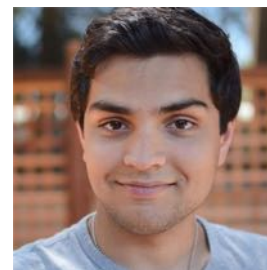
Brahm
Capoor
bcapoor



Maya
Ziv
mziv



Gaby
Candes
gcandes



Andrew
Tierno
atierno



Christian
Davis
cdavis



Approach #1: Needle in Haystack

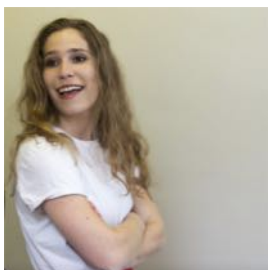
Query: "Davis"



Chris
Piech
cpiech



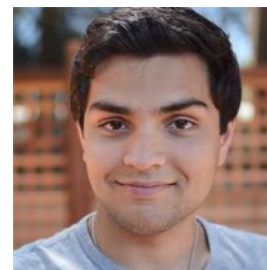
Brahm
Capoor
bcapoor



Maya
Ziv
mziv



Gaby
Candes
gcandes



Andrew
Tierno
atierno



Christian
Davis
cdavis



Approach #1: Needle in Haystack

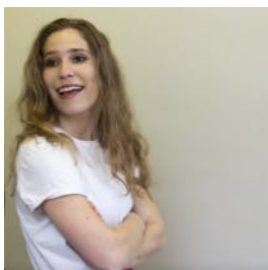
Query: "Davis"



Chris
Piech
cpiech



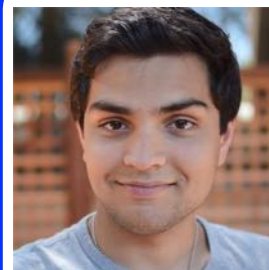
Brahm
Capoor
bcapoor



Maya
Ziv
mziv



Gaby
Candes
gcandes



Andrew
Tierno
atierno



Christian
Davis
cdavis



Approach #1: Needle in Haystack

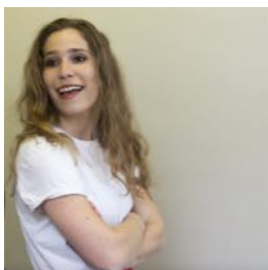
Query: "Davis"



Chris
Piech
cpiech



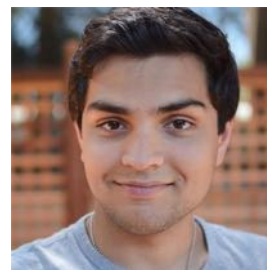
Brahm
Capoor
bcapoor



Maya
Ziv
mziv



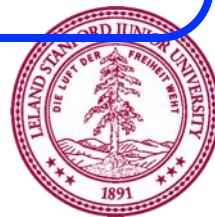
Gaby
Candes
gcandes



Andrew
Tierno
atierno



Christian
Davis
cdavis



Too Slow!



You design the solution



First, lets get our feet wet

Parse File Lines

index

0 1 2 3 ... 12 ... 17 18
"Alisha Adam (aadam)"

line.substring(13, 18);

line.substring(0, 12);



Section Leader Who

```
/* Print Query Responses
 * -----
 * Print all students who have the query as either
 * their sunetId or as one of their names
 * Example queries:
 * "Chris", "Capoor", "Maya", "mziv"
 */
private void printQueryResponses(String query) {

    // TODO: your code here

}
```



Approach #2: HashMap

Database HashMap

Key	Value
piech	["Chris Piech (cpiech)"]
cpiech	["Chris Piech (cpiech)"]
chris	["Chris Collins (ccollins)" "Chris Koenig (ckoenig)" "Chris Piech (cpiech)" "Chris Wang (cwang)"]
wang	["Anna Wang (awang)", "Avery Wang (awang)", "Chris Wang (cwang)", "Lisa Wang (lwang)", ...]
...	



Approach #2: HashMap

Database HashMap

Key

Value

*How do we build
the hashmap?*



Approach #2: HashMap

Database HashMap

Key

Value

*Originally no
"chris"
key...*



Approach #2: HashMap

Database HashMap

Key

Value

*When we see the **first** “Chris”*



Approach #2: HashMap

Database HashMap

Key

Value

chris



```
[  
  "Chris Collins (ccollins)"  
]
```

When we see the *first* "Chris"



Approach #2: HashMap

Database HashMap

Key

Value

chris



```
[  
  "Chris Collins (ccollins)"  
  "Chris Koenig (ckoenig)"  
]
```

When we see the **second** "Chris"



Approach #2: HashMap

Database HashMap

Key

Value

chris



```
[  
  "Chris Collins (ccollins)"  
  "Chris Koenig (ckoenig)"  
  "Chris Piech (cpiech)"  
]
```

When we see the **thrid** “Chris”



Approach #2: HashMap

Database HashMap

Key

Value

chris



```
[  
  "Chris Collins (ccollins)"  
  "Chris Koenig (ckoenig)"  
  "Chris Piech (cpiech)"  
  "Chris Wang (cwang)"  
]
```

When we see the **fourth** "Chris"





Know how to do this

Imagine a String -> String hashmap:

```
HashMap<String, String> original =  
    new HashMap<String, String>();
```



Original

Key Value

“Brahm” → “Dog”

“Maya” → “Cat”

“Gabby” → “Dog”

“Chris” → “Zebra”



Reversed

Key Value

“Dog” → [“Brahm”, “Gabby”]

“Cat” → “[Maya]”

“Zebra” → “[Chris]”



Know how to do this

```
/**
 * Reverse Map:
 * Perhaps the best hashmap practice...
 * Try and work through it before next weeks section
 */
private HashMap<String, ArrayList<String>> reverse(
    HashMap<String, String> original) {
    // TODO: your code here
    return null;
}
```

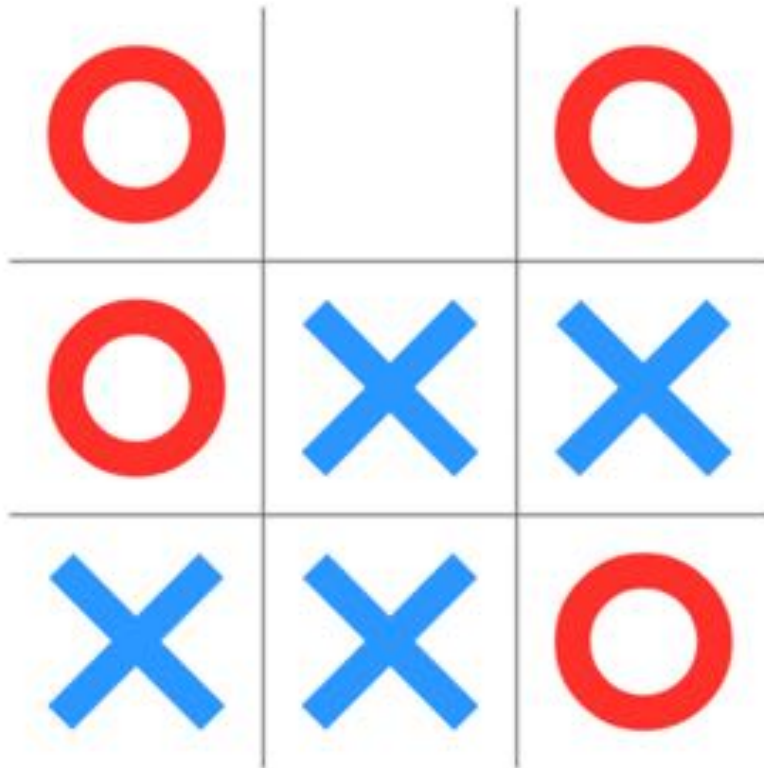






What Collection?

Tic Tac Toe board

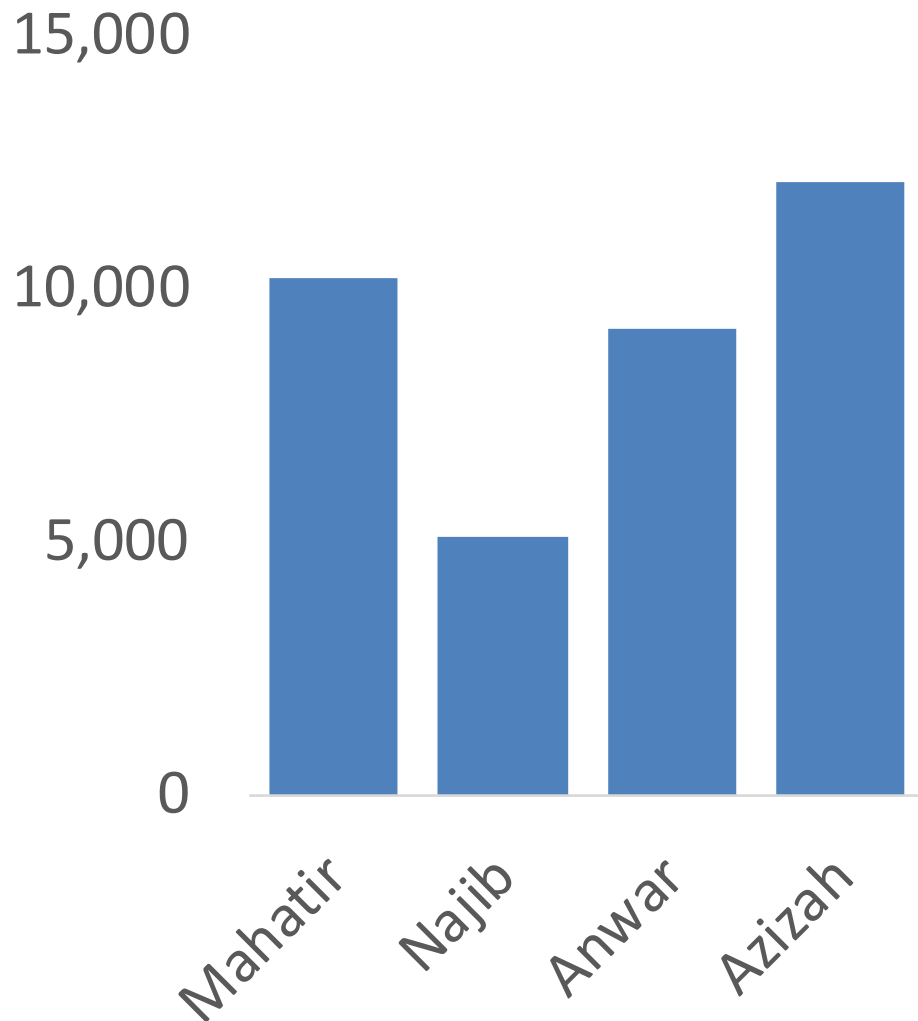


`char[][]`



What Collection?

Election Vote Counter



**HashMap<String,
Integer>**



What Collection?

Wikipedia

WIKIPEDIA
The Free Encyclopedia

English
5 802 000+ articles

日本語
1 138 000+ 記事

Español
1 504 000+ artículos

Français
2 080 000+ articles

中文
1 043 000+ 條目


Kiswahili
48 000+

Deutsch
2 270 000+ Artikel

Русский
1 527 000+ статей

Italiano
1 503 000+ voci

Português
1 016 000+ artigos

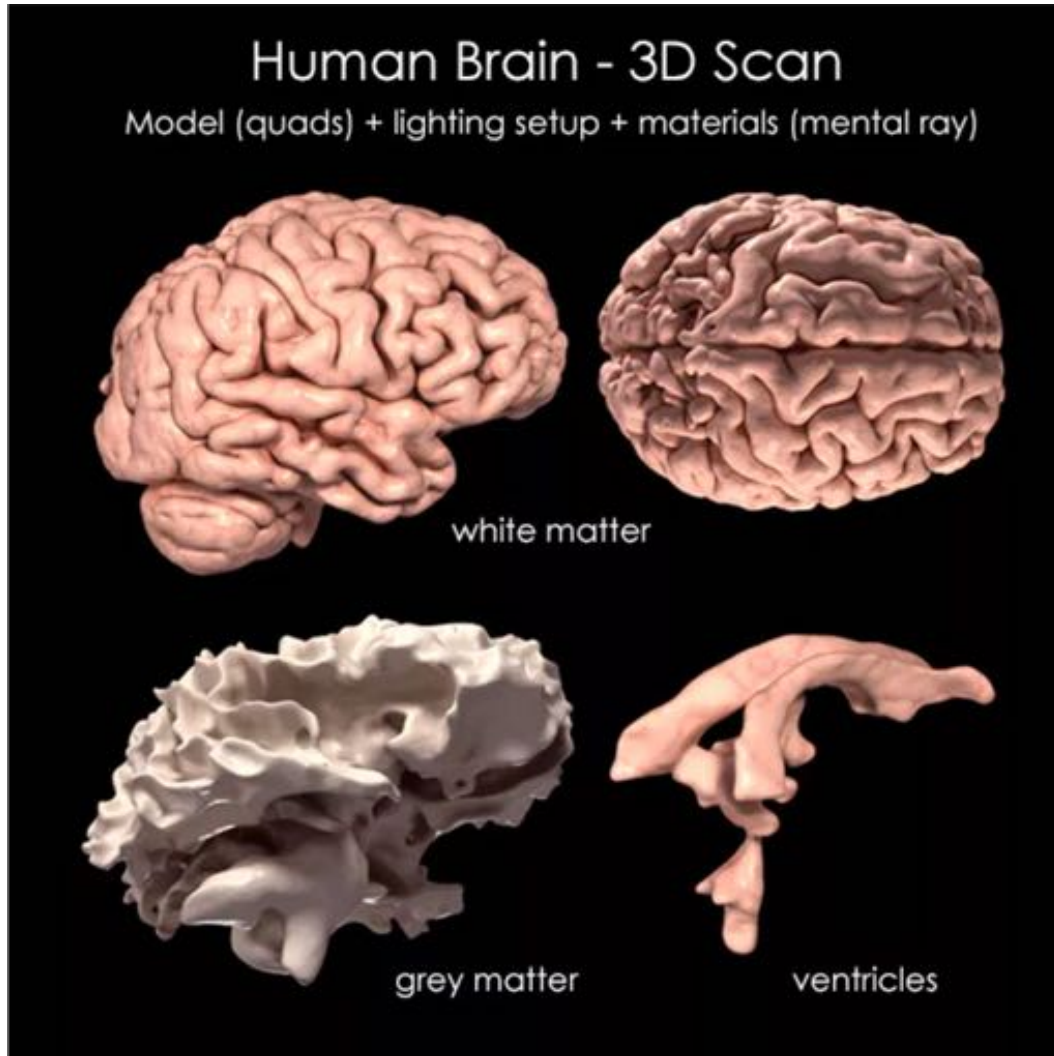


**HashMap<String,
ArrayList<String>>**



What Collection?

3D Brain Scan

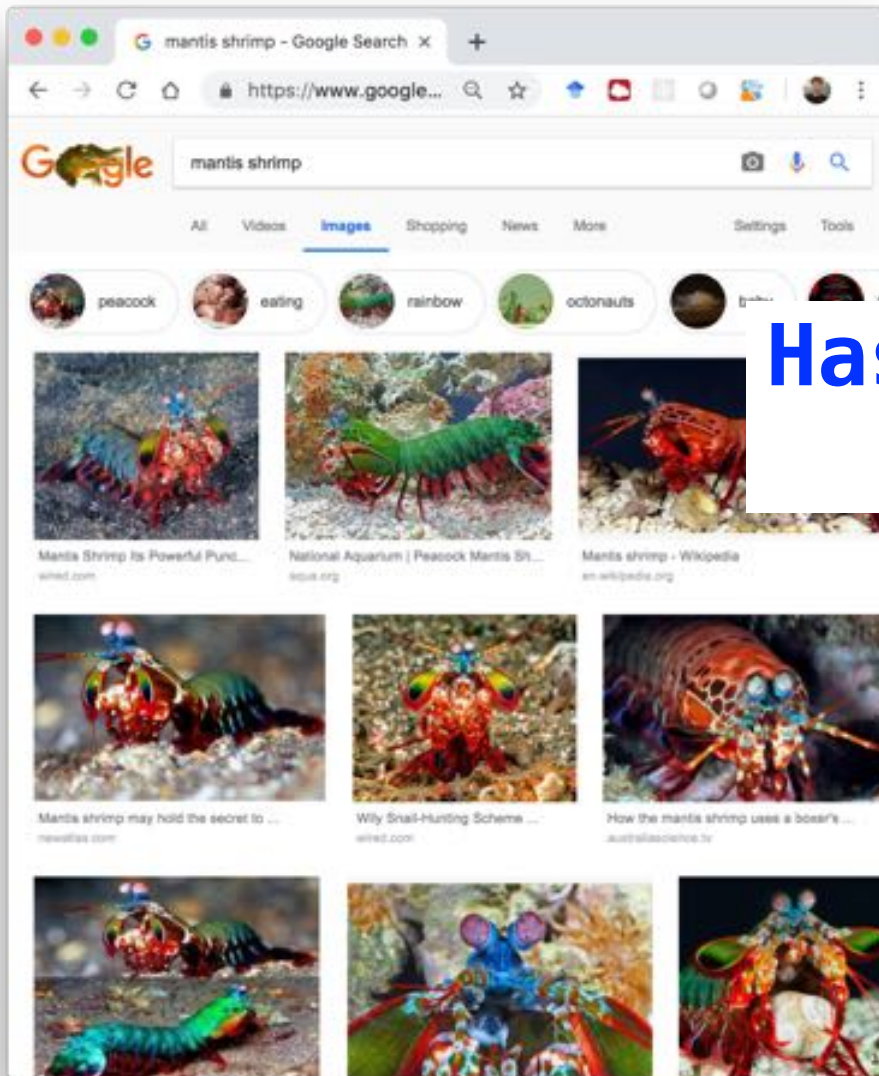


`double[][][]`



What Collection?

Google Images



`HashMap<String,
ArrayList<GImage>>`

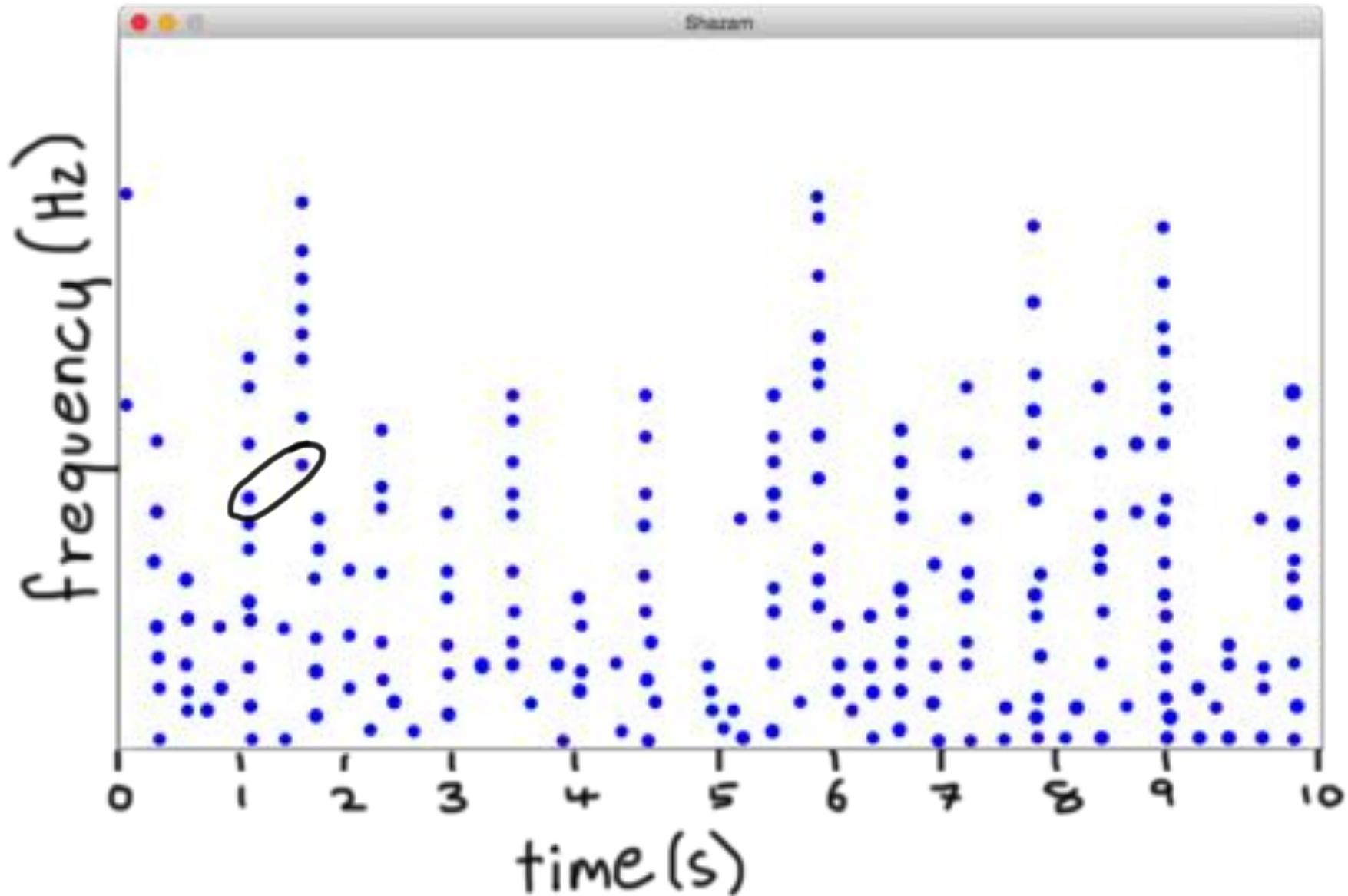


What Collection?

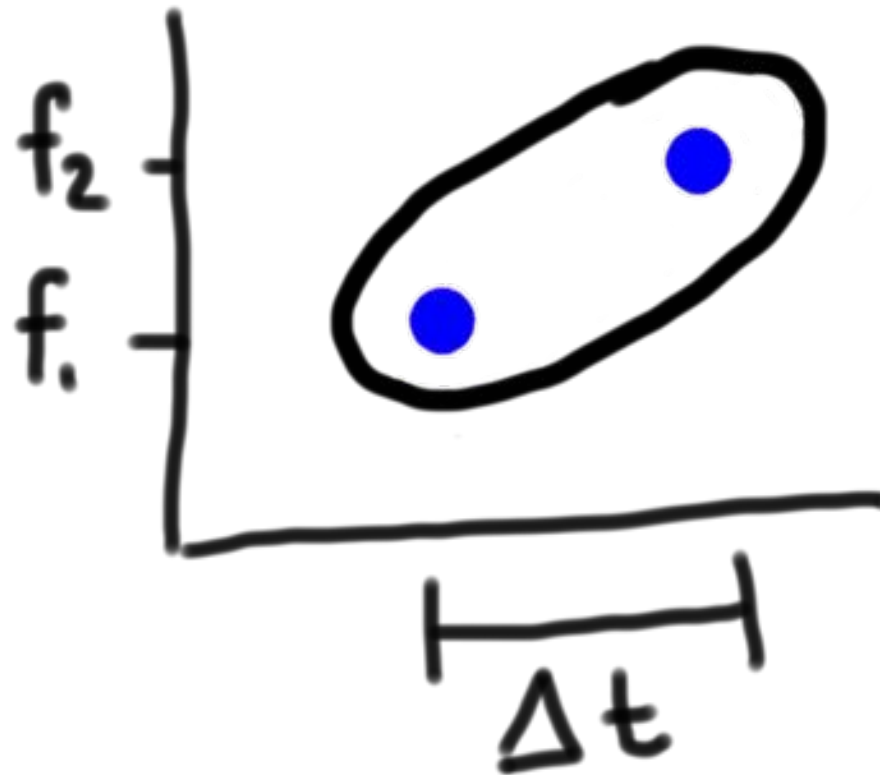
Shazam



Shazam Query



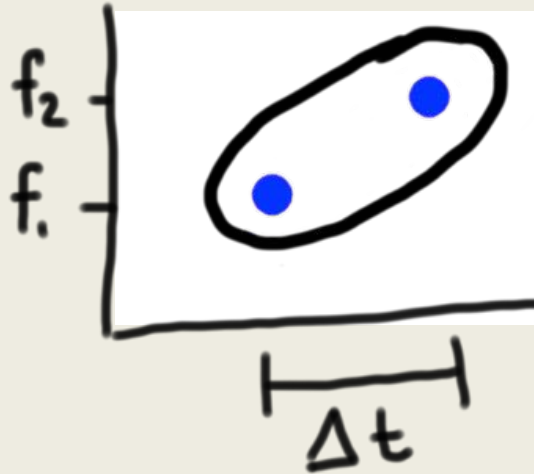
Note Pair



HashMap NotePair -> Song List

Shazam

Key:

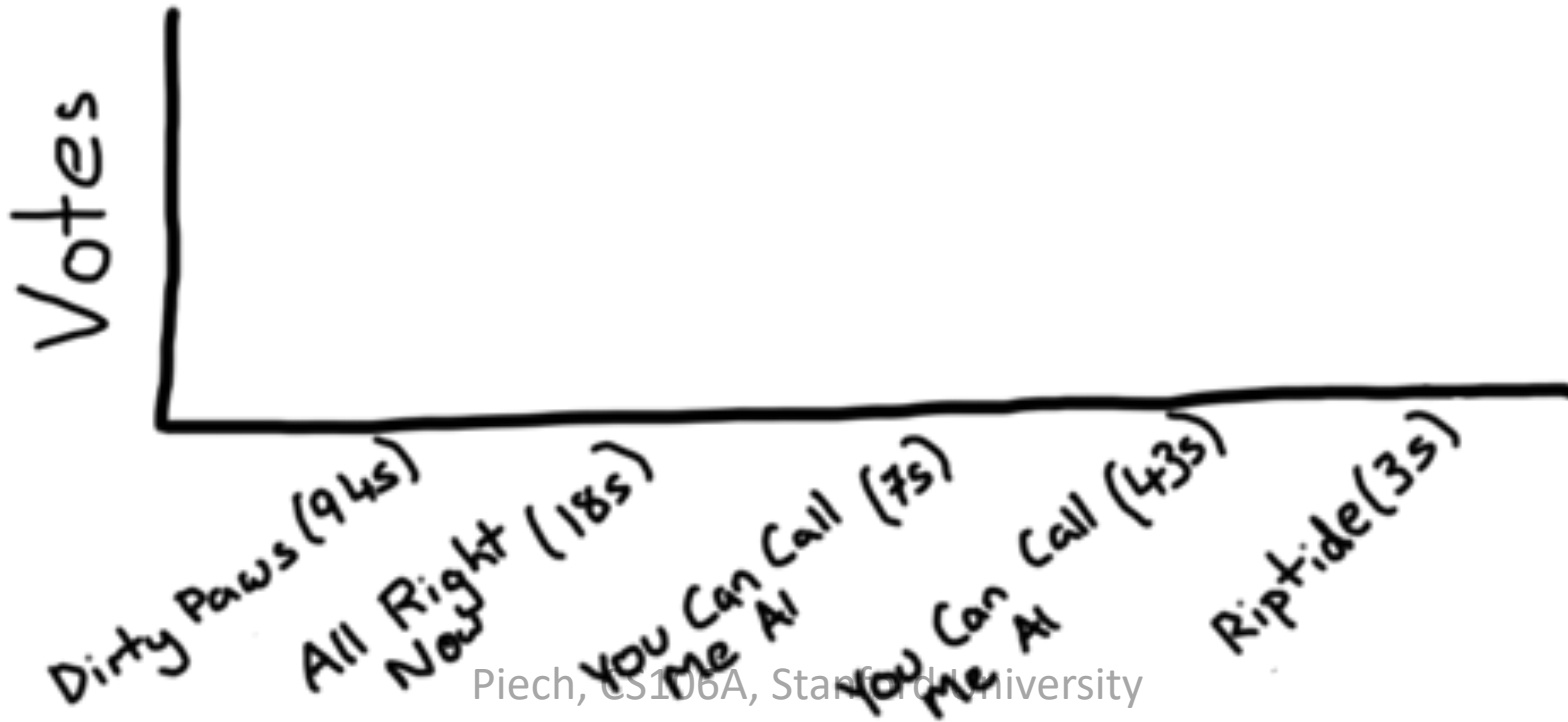
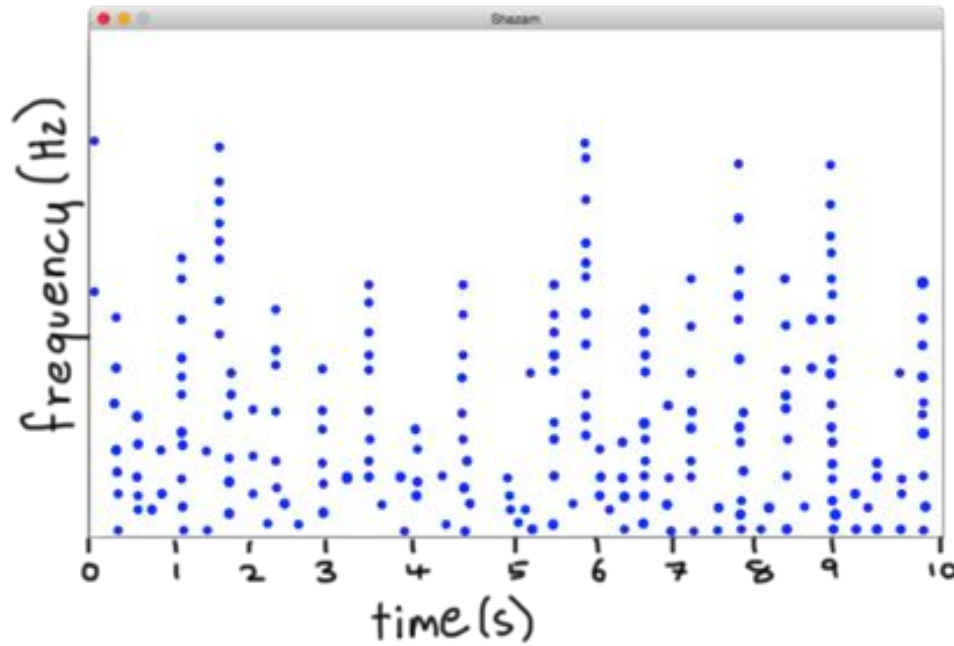


Value:

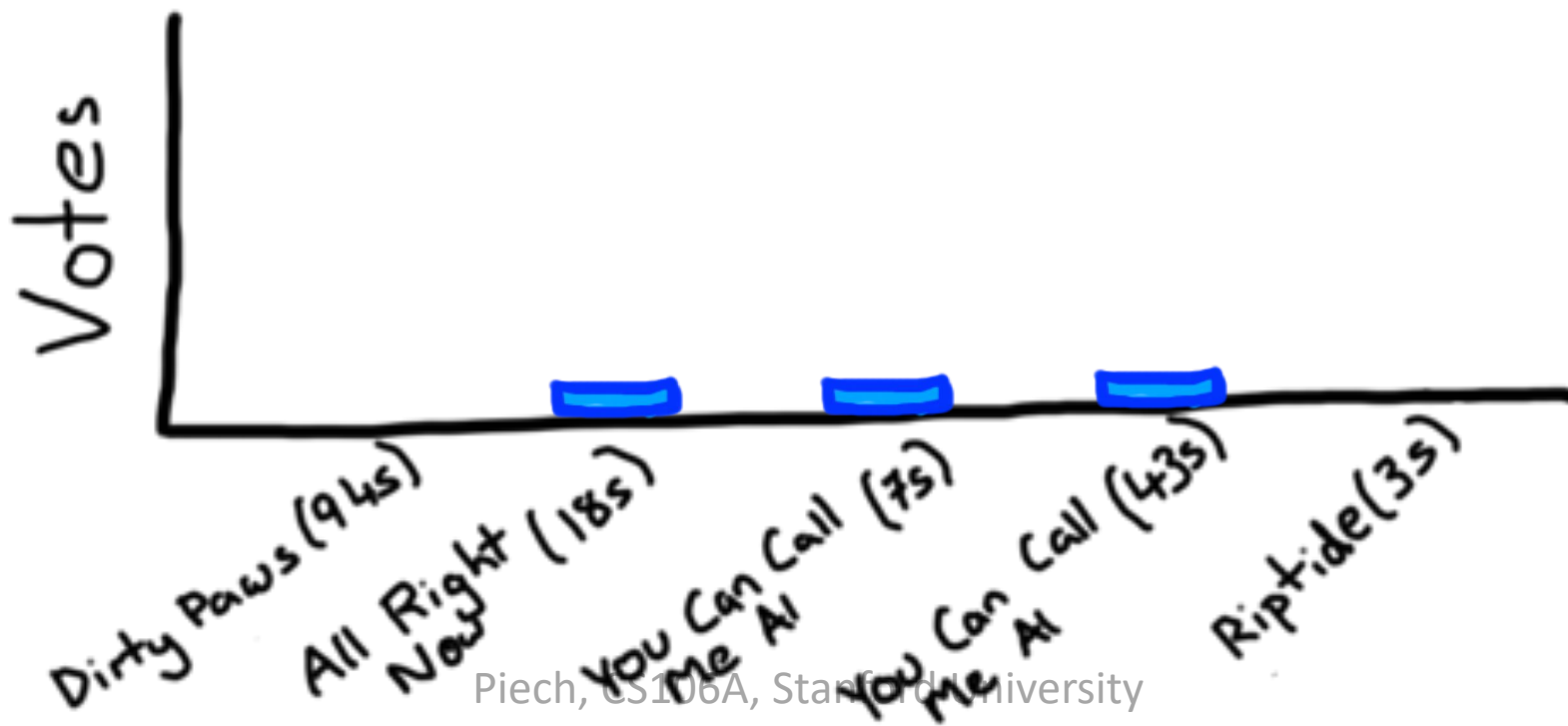
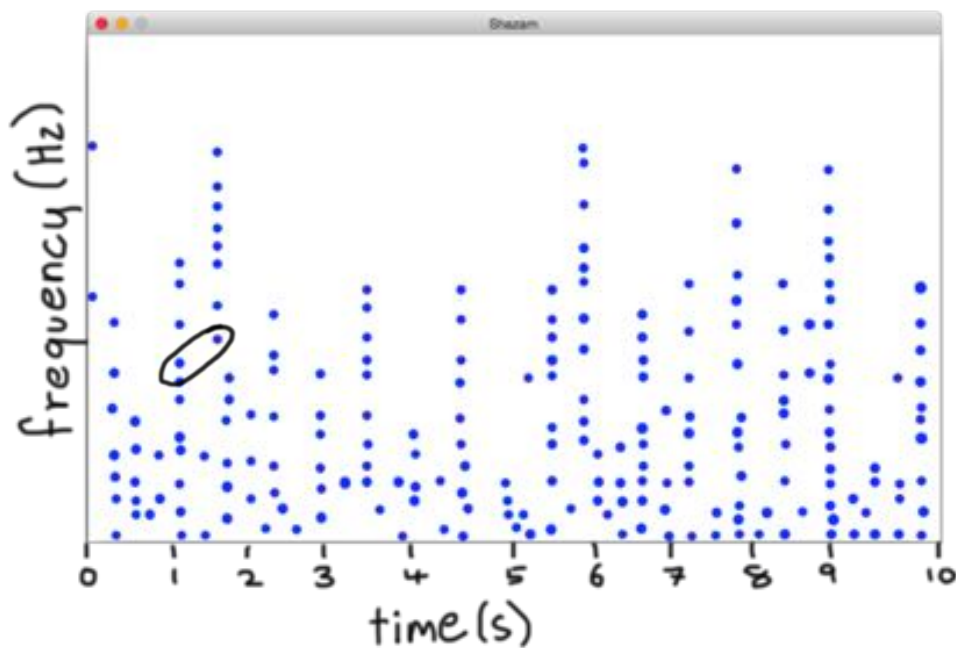
You Can Call Me Al – Paul Simon. 7s,
You Can Call Me Al – Paul Simon. 43s,
All Right Now – Police. 18s



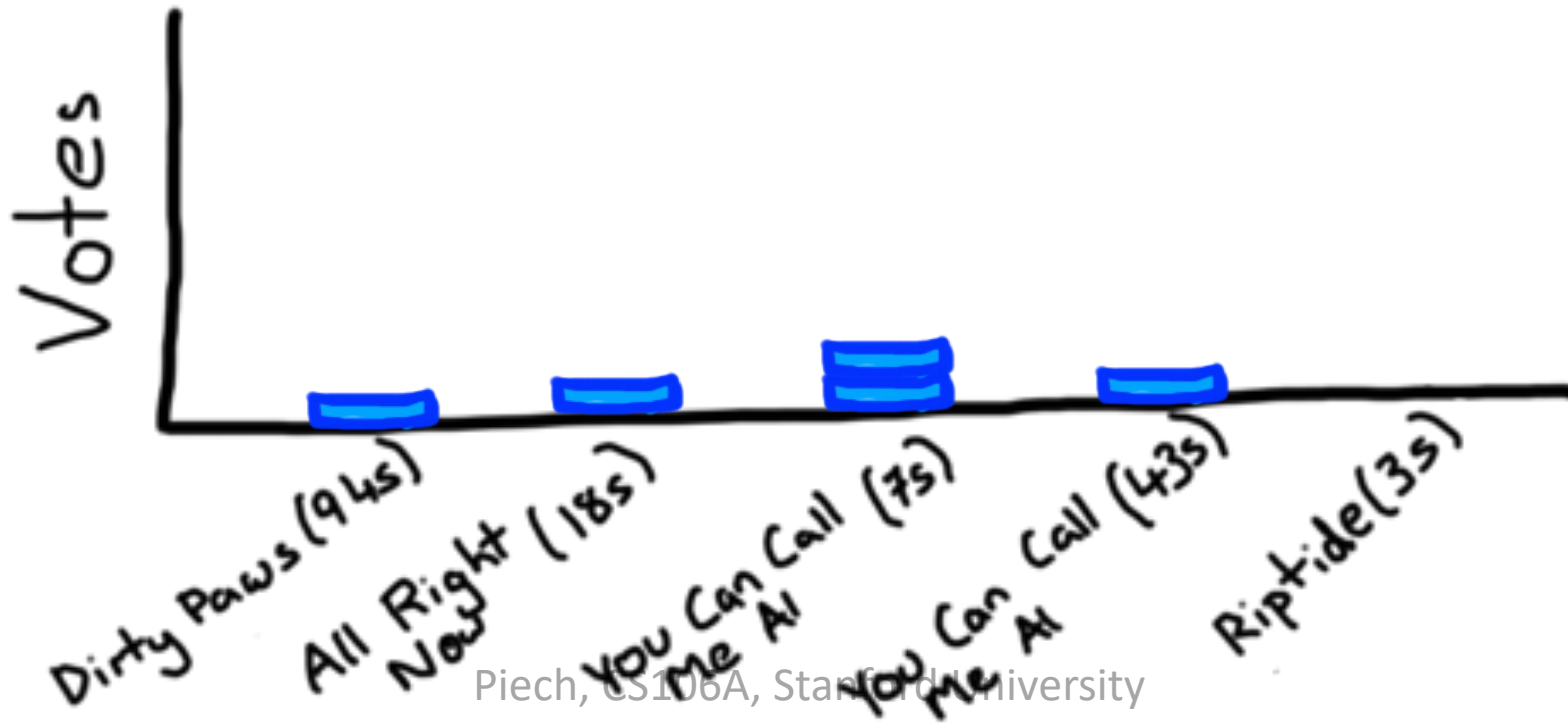
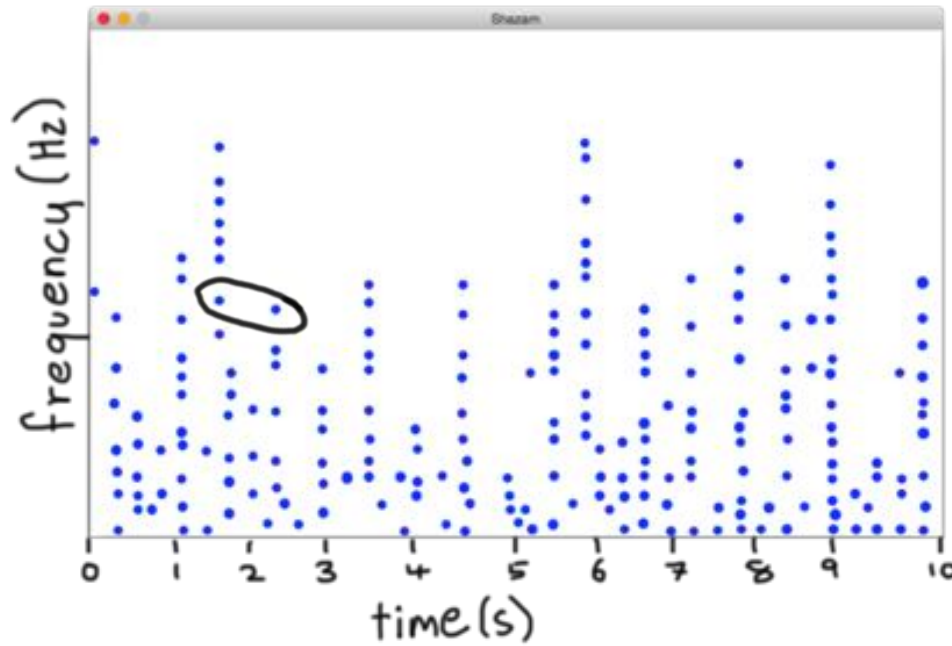
HashMap NotePair -> Song List



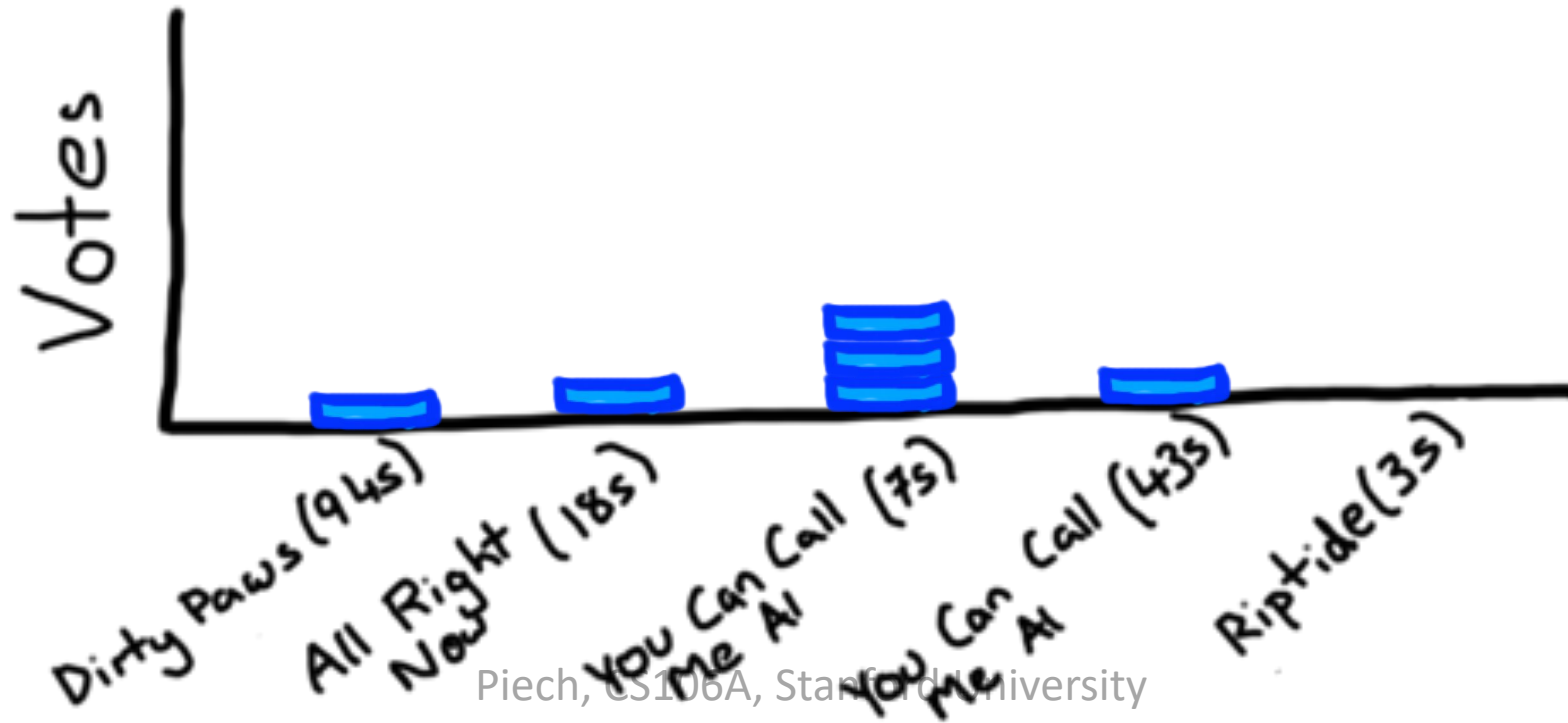
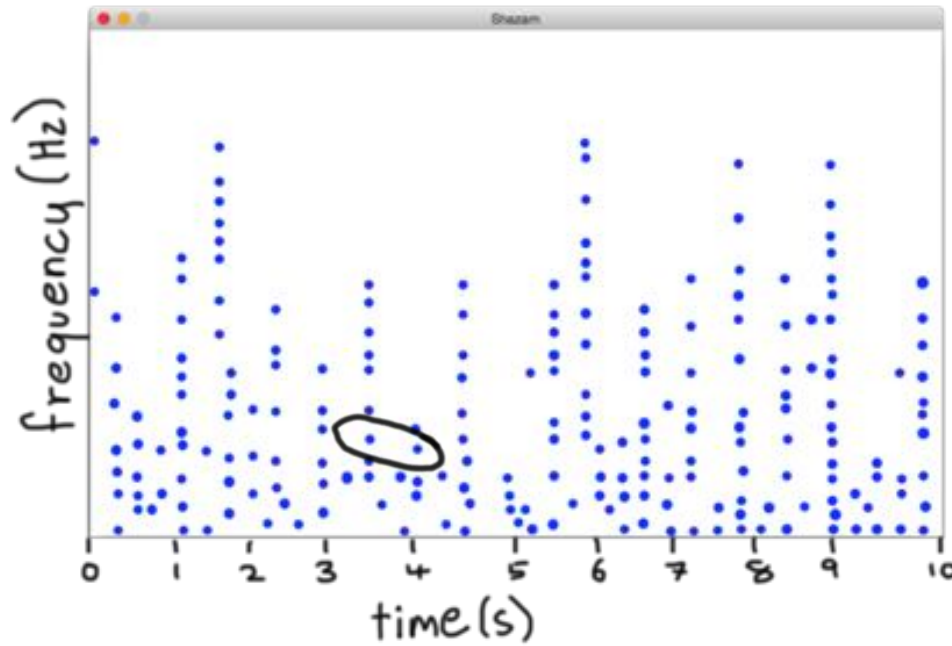
HashMap NotePair -> Song List



HashMap NotePair -> Song List



HashMap NotePair -> Song List



HashMap NotePair -> Song List

