LEC 17

CSE 123

Hashing

Questions during Class?
Raise hand or send here

sli.do #cse123

BEFORE WE START

Talk to your neighbors:

Where do you keep your keys/wallet/phone at home so you don't lose them?

Respond on sli.do!

Instructor: Brett Wortzman

TAs:

Arohan	Jonah	Kavya	Eeshani	Trien
Ashar	Brice	Misha	Aidan	Evan
Sean	Chris	Kieran	Cora	Rena
Chloe	Elden	Sahana	Dixon	Katharine
Jenny	Ishita	Anirudh	Nhan	Anya
Nate	Kuhu	Crystal		

Now playing: CSE 123 26wi Lecture Tunes

Announcements

- Programming Project 3 due today, Friday 3/3 at 11:59pm
- Creative Project 3 out, due Friday, 3/13 at 11:59pm
- Resubmission Cycle 6 due **tonight at 11:59pm**
  - ***P1***, C2, P2 eligible
- R8 / R-Brett will open on Monday

Data structures so far

- **Lists**
  - Maintain an ordered sequence of elements
  - Provides get(), add(), remove(), ...
  - Studied two implementations: ArrayIntList and LinkedIntList

- **Sets**
  - Maintain a collection of elements
  - Provides contains(), add(), remove(), ...
  - Implementations?

Set implementations

	ArraySet(?)	LinkedSet(?)	SortedArraySet	TreeSet	HashSet
contains()	O(n)	O(n)			
add()	O(n)	O(n)			
remove()	O(n)	O(n)			

Set implementations

	ArraySet(?)	LinkedSet(?)	SortedArraySet	TreeSet	HashSet
contains()	O(n)	O(n)	O(log(n))		
add()	O(n)	O(n)	O(n)		
remove()	O(n)	O(n)	O(n)		

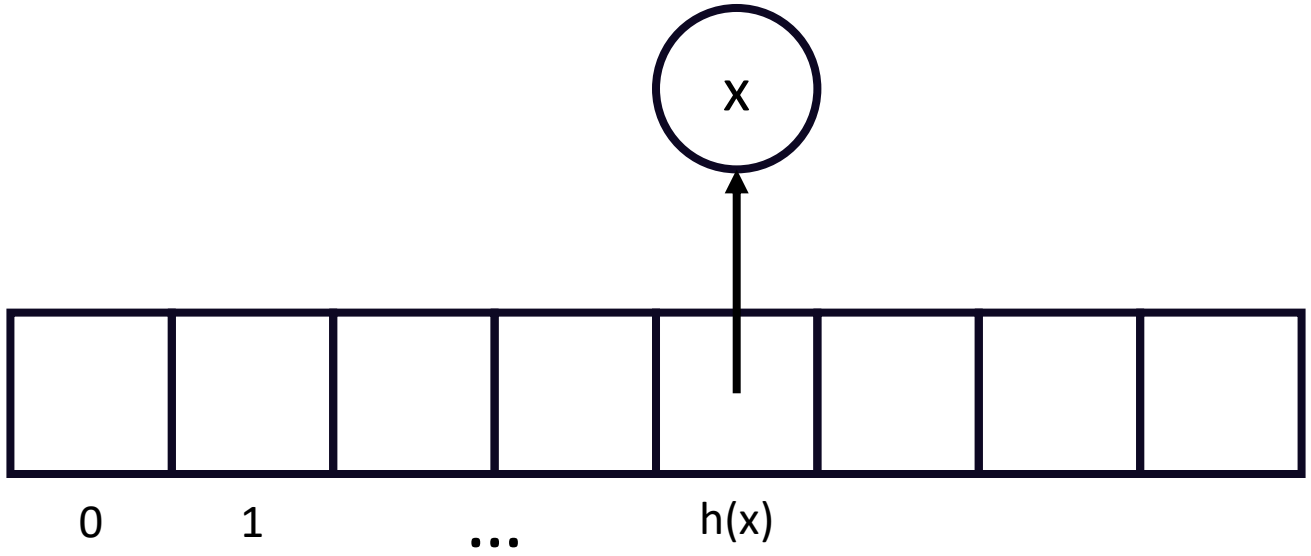
Set implementations

	ArraySet(?)	LinkedSet(?)	SortedArraySet	TreeSet	HashSet
contains()	O(n)	O(n)	O(log(n))	O(log(n))*	
add()	O(n)	O(n)	O(n)	O(log(n))*	
remove()	O(n)	O(n)	O(n)	O(log(n))*	

* assuming tree is balanced

Hash Table

- Define a **hash function** h(x) that turns any value into an integer
  - Call this the values **hash code**
- Create a big array
- Store each value in the array at index h(x)



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Set implementations

	ArraySet(?)	LinkedSet(?)	SortedArraySet	TreeSet	HashSet
contains()	O(n)	O(n)	O(log(n))	O(log(n))*	O(1)**
add()	O(n)	O(n)	O(n)	O(log(n))*	O(1)**
remove()	O(n)	O(n)	O(n)	O(log(n))*	O(1)**

* assuming tree is balanced

** with some assumptions

What if two items hash to the same slot?

- Nothing stops the hash function from returning the same number for two different items!
- Our hash table needs some way to handle this...
- Any ideas?

What if two items hash to the same slot?

- Nothing stops the hash function from returning the same number for two different items!
- Our hash table needs some way to handle this...
- Any ideas?
- Common solutions:
  - Probing: look at some other related slots
  - Chaining: make each slot a list(!)

What is Linear Probing?

A way to resolve collisions by adding the element in the next available spot

Regular Hash Function

h(x) = x % size

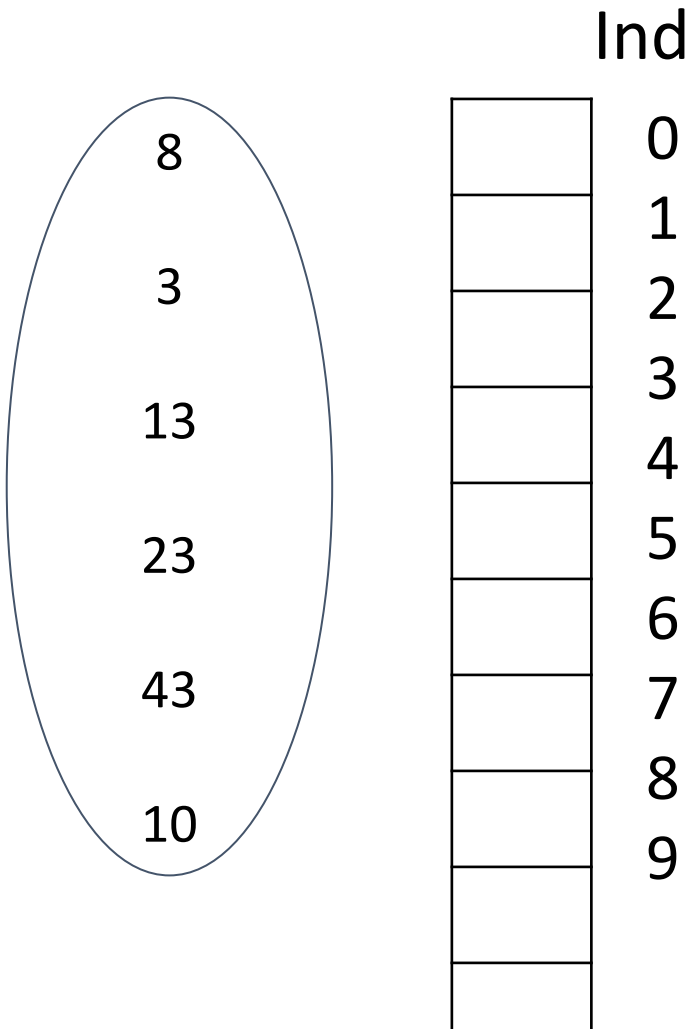
Hash Function (if collision)

h'(x) = [h(x) + f(i)] % size

f(i) = i

What is Linear Probing?

h(x) = x % size h'(x) = [h(x) + f(i)] % size f(i) = i



What is Quadratic Probing?

A way to resolve collisions by adding the element in the next available spot (quadratically)

Regular Hash Function

h(x) = x % size

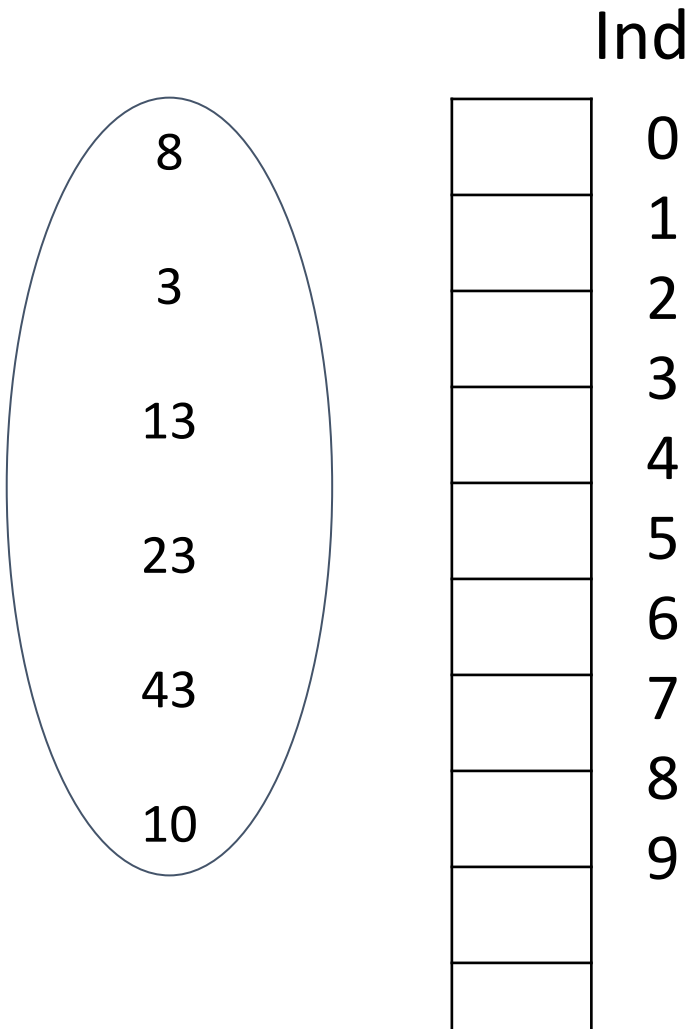
Hash Function (if collision)

h'(x) = [h(x) + f(i)] % size

f(i) = i^2

What is Quadratic Probing?

h(x) = x % size **h'(x) = [h(x) + f(i)] % size** **f(i) = i^2**



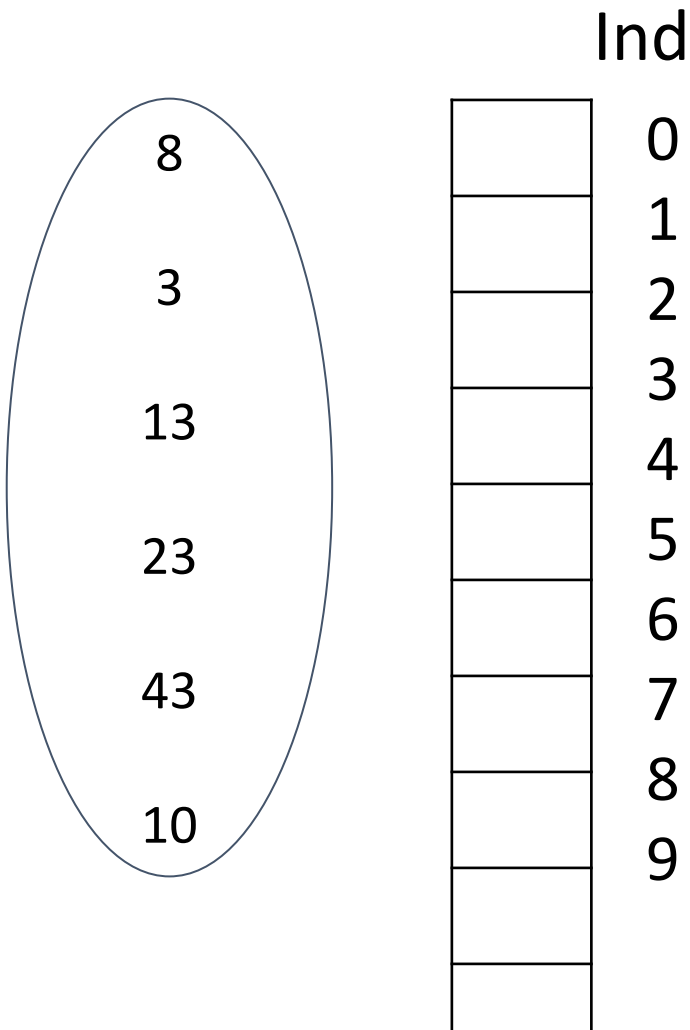
What is Chaining?

A way to resolve collisions by creating a LinkedList at that Index (also called a “bucket”)

- Combines both features of ArrayList Indexing and the ease of adding values using LinkedLists

What is Chaining?

h(x) = x % size



Recap (Comparison)

Linear Probing	Quadratic Probing	Chaining
A way to resolve collisions by adding the element in the next available spot	A way to resolve collisions by adding the element in the next available spot (quadratically)	A way to resolve collisions by creating a LinkedList at that Index (also called a “bucket”)

Why Chaining?

Clustering - A tendency for data to clump together when using solutions to Collisions like Linear and Quadratic probing

- Linear and Quadratic Probing often result in “Clustering”
- Inefficient use of space in the table
- This means the Runtimes will also be slower

1	2	3	4	5	6				7							8	9		

Why Chaining?

- Hashing can reduce it down to O(1)
- “Load Factor” - lambda ($\boldsymbol{\lambda}$)
  - the number of values in each LinkedList
- Finding the index in the Table is O(1)
- Finding value in LinkedList is O($\boldsymbol{\lambda}$) or essentially O(1)

Standard Java hashCode

```
hash = 0
for (each field) {
    hash = 31 * hash + hash(field)
}
```