LEC 17

CSE 123

Hashing

Questions during Class?

Raise hand or send here

sli.do #cse123A

BEFORE WE START

Talk to your neighbors:

How do you remember where you put things?

Instructor: Nathan Brunelle

TAs:	Arohan	Ashar	Neha	Rohini	Rushil
	Ido	Zachary	Sebastian	Joshua	Sean
	Hayden	Caleb	Justin	Heon	Rashad
	Srihari	Benoit	Derek	Chris	Bhaumik
	Kuhu	Kavya	Cynthia	Shreya	Ashley
	Ziao	Kieran	Marcus	Crystal	Eeshani
	Prakshi	Packard	Cora	Dixon	Nichole
	Niyati	Trien	Lawrence	Evan	Cady

Announcements

- Programming Project 3 due today, Friday 5/30 at 11:59pm
- Creative Project 3 out, due Friday, June 6 at 11:59pm
- Resubmission Cycle 6 due **tonight at 11:59pm**
  - ***P1***, C2, P2 eligible
- R7 / R-Bucks will open on Monday
- Final Exam: Wednesday, June 11 at 12:30pm – 2:20pm
  - Left-handed desk request form, closes Tuesday, June 3
  - Details and resources posted later today

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(?)	TreeSet	HashSet
contains()	O(n)	O(n)		
add()	O(n)	O(n)		
remove()	O(n)	O(n)		

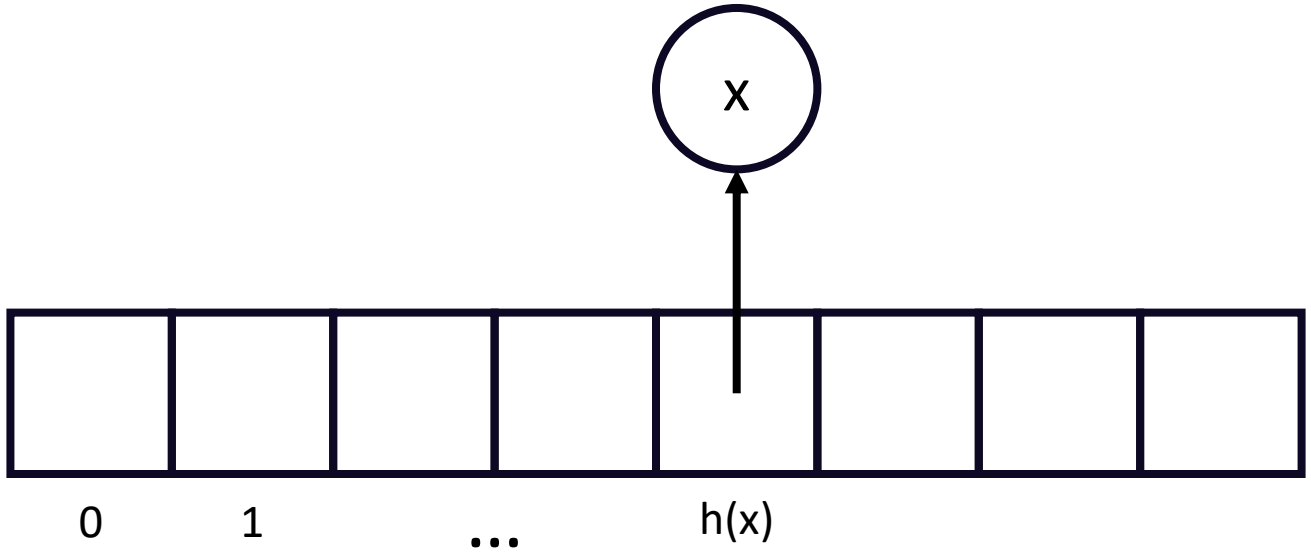
Set implementations

	ArraySet(?)	LinkedSet(?)	TreeSet	HashSet
contains()	O(n)	O(n)	O(log(n))*	
add()	O(n)	O(n)	O(log(n))*	
remove()	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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* assuming tree is balanced

Set implementations

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

* assuming tree is balanced

** with some assumptions

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

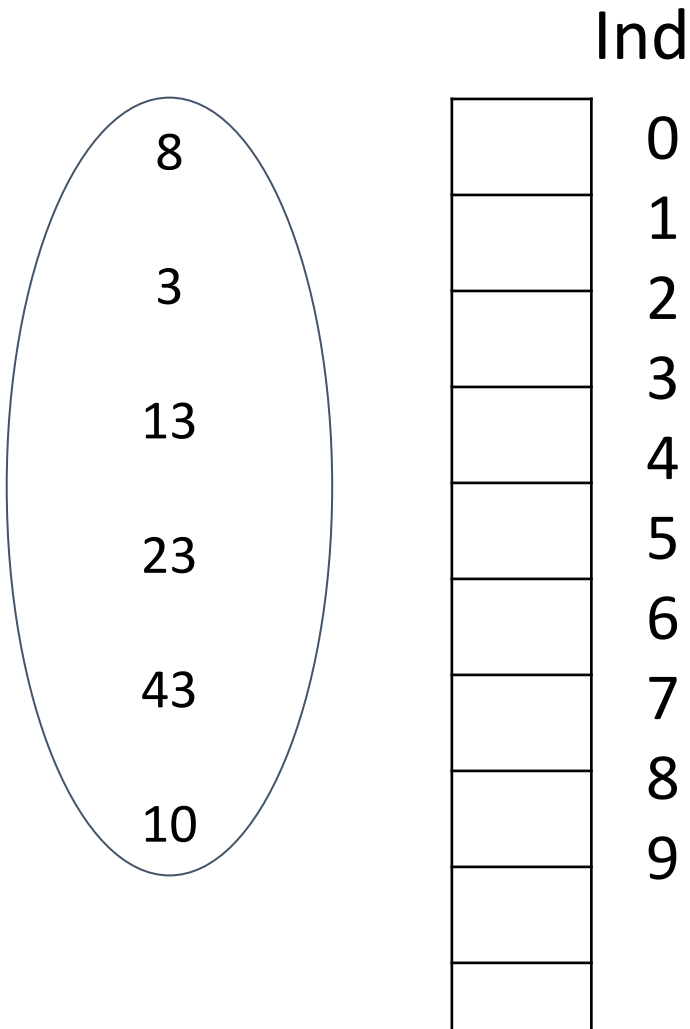
Hash Function (if collision)

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

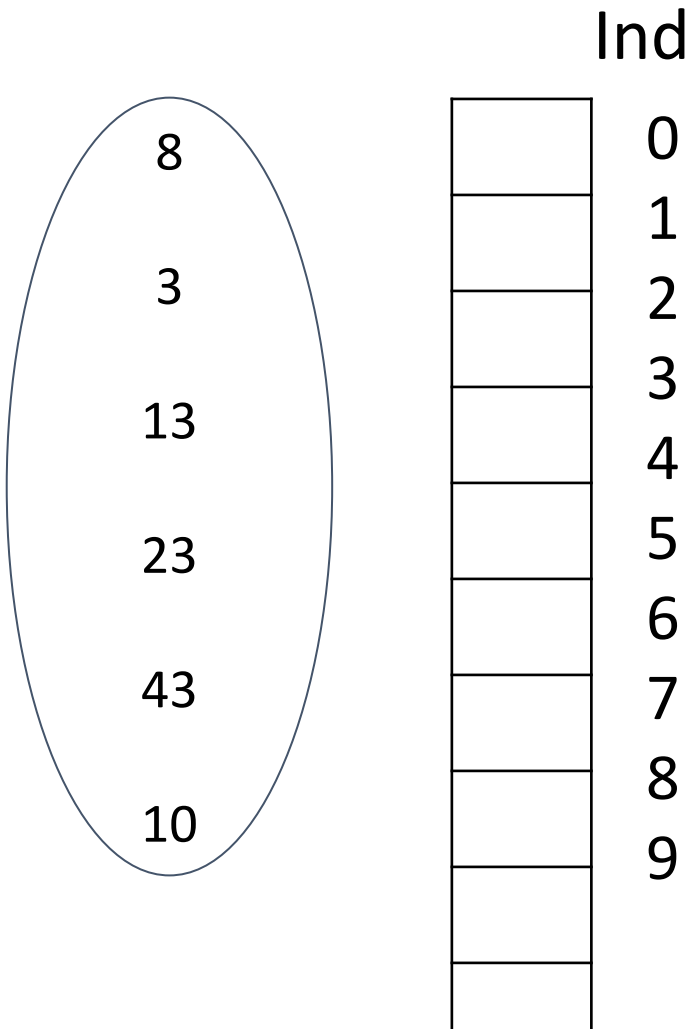
Hash Function (if collision)

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**



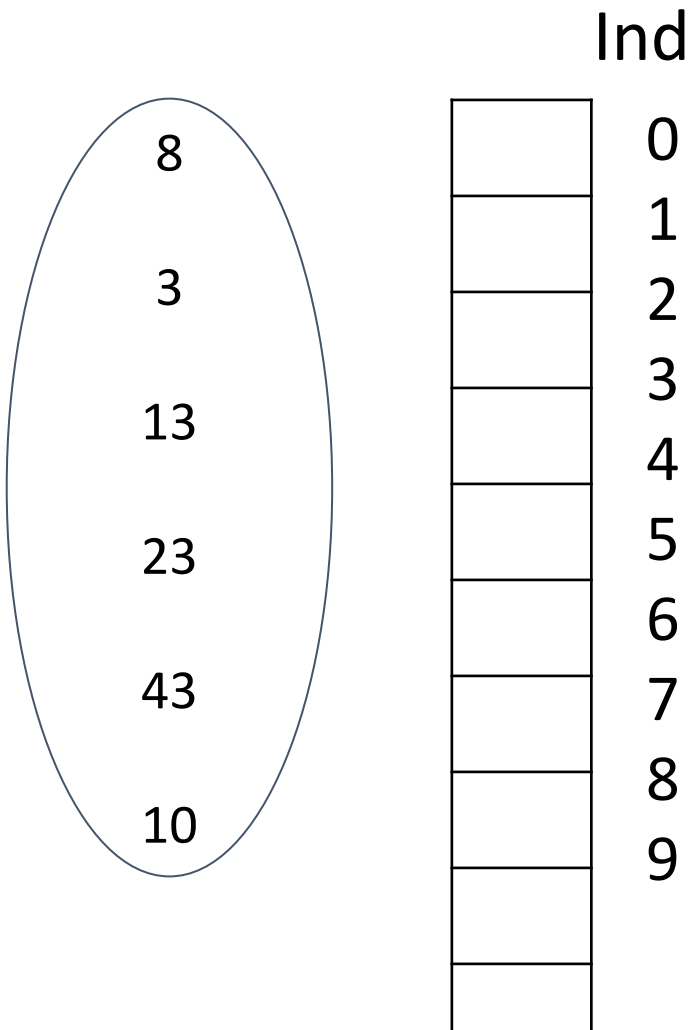
What is ⭐Chaining?

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)
}
```