CS151 Intro to Data Structures

Hashmaps

Announcements & Outline

Next homework (HashMaps and QuickSort) due Sunday Dec 1st

Today:

- HashMap Review
- ProbeHashMaps
- HW7 discussion

Hash Map Reivew

Hash Map:

- Efficient data structure with constant time* access, insertion, and removal
- * assuming no collisions or expansions

Hash Function Review

Book’s `AbstractHashMap` hash method uses:

h_1`(k) = k.hashCode()` // java memory address

h_2`(x) = ((ax + b) % p) % N`

```
h = h2(h1(k))
```

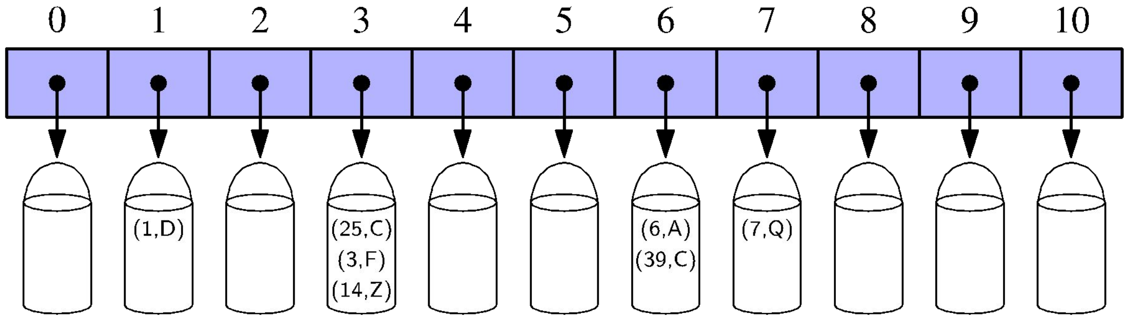
Performance Analysis

	ArrayMap	Collision Resistant Hash Map
get		
put		
remove		

Review: Handling Collisions

ChainHashMap:

- When more than one key hash to the same index, we have a bucket
- Each index holds a collection of entries



- Worst case:
  - all elements collide into the same bucket
  - O(n) operations

Open Addressing and Probing

- Example: $h(x) = x\%13$
- insert 18(5), 41(2), 22(9), 44(5), 59(7), 32(6), 31(5), 73(8)

Keep "*probing*"

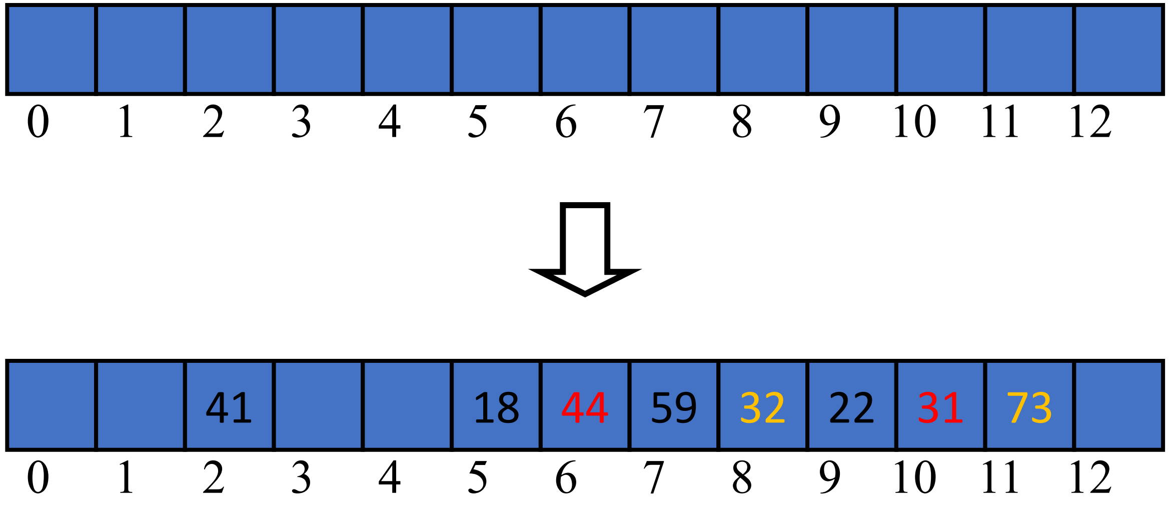
(h(k)+1)%n

(h(k)+2)%n

….

(h(k)+i)%n

until you find an empty slot!



0	1	2	3	4	5	6	7	8	9	10	11	12

		41			18	44	59	32	22	31	73	
0	1	2	3	4	5	6	7	8	9	10	11	12

ProbeHashMap

Let’s look at an implementation of ProbeHashMap

Open Addressing and Probing

Linear Probing (what we just saw):

- Keep "*probing*" until you find an empty slot

  (h(k)+1) % n
  (h(k)+2) % n
  ....
  (h(k)+i) % n

- Colliding items cluster together – future collisions to cause a longer sequence of probes

Open Addressing and Probing

Quadratic Probing:

- Keep "*probing*" until you find an empty slot

  (h(k)+f(1)) % n

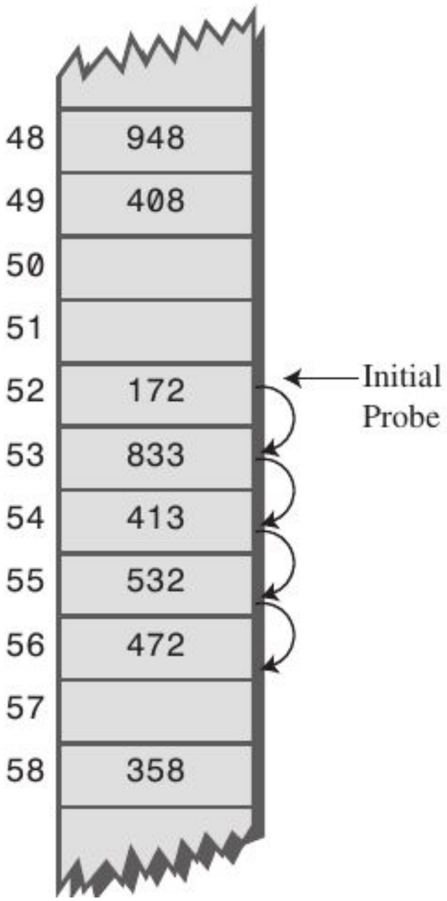
  (h(k)+f(2)) % n

  ….

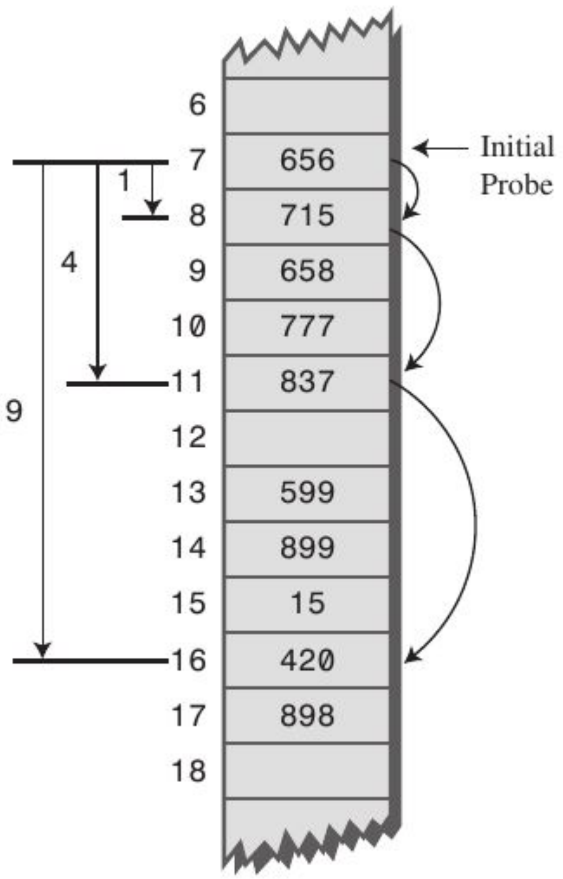
  (h(k)+f(i)) % n

  where f(i) = i^2

Linear Probing vs Quadratic Probing



Linear Probing



Quadratic Probing

- Quadratic probing still creates large clusters!

- Unlike linear probing, they are clustered away from the initial hash position

- If the primary hash index is x, probes go to x+1, x+4, x+9, x+16, x+25 and so on, this results in ***Secondary Clustering***

Approach #3: **Double Hashing**

Let’s try to avoid clustering.

To probe, let’s use a **second hash function**

- Keep “*probing*” until you find an empty slot

  (h(k)+f(1)) % n

  (h(k)+f(2)) % n

  ….

  (h(k)+f(i)) % n

Where f(i) = i * **h’(k)**

Approach #3: **Double Hashing**

Keep "*probing*" until you find an empty slot

(h(k)+f(1)) % n

(h(k)+f(2)) % n

....

(h(k)+f(i)) % n

Where f(i) = i * **h'(k)**

A common choice for **h'(k)** = q - (k % q)
where q is prime and < n

Example

- Insert 18, 41, 22, 44, 59, 32, 31, 73

probe:

(h(k) + f(k)) % n

h(k) = k % 13

f (k) = i * **h'(k)**

h'(k) = 7 - k % 7

k	*h* (*k*)	h'(k)	Probes		
18	5	3	5		
41	2	1	2		
22	9	6	9		
44	5	5	5	10	
59	7	4	7		
32	6	3	6		
31	5	4	5	9	0
73	8	4	8		

0	1	2	3	4	5	6	7	8	9	10	11	12

⇩

31		41			18	32	59	73	22	44		
0	1	2	3	4	5	6	7	8	9	10	11	12

Performance Analysis

	ChainHashMap Best Case	ChainHashMap Worst Case	ProbeHashMap Best Case	ProbeHashMap Worst Case
get				
put				
remove				

Which is better in practice?

Open Addressing vs Chaining

- Probing is significantly faster in practice
- locality of references – much faster to access a series of elements in an array than to follow the same number of pointers in a linked list

Performance Analysis

	ArrayMap	HashMap with good hashing and good probing
get		
put		
remove		

Performance of Hashtable

	array	linked list	BST (balanced)	HashTable
search				
insert				
remove				

Load Factor

- HashMaps have an underlying array... what if it gets full?
  - For ChainHashMap collisions increase
  - For ProbeHashMap we need to resize!

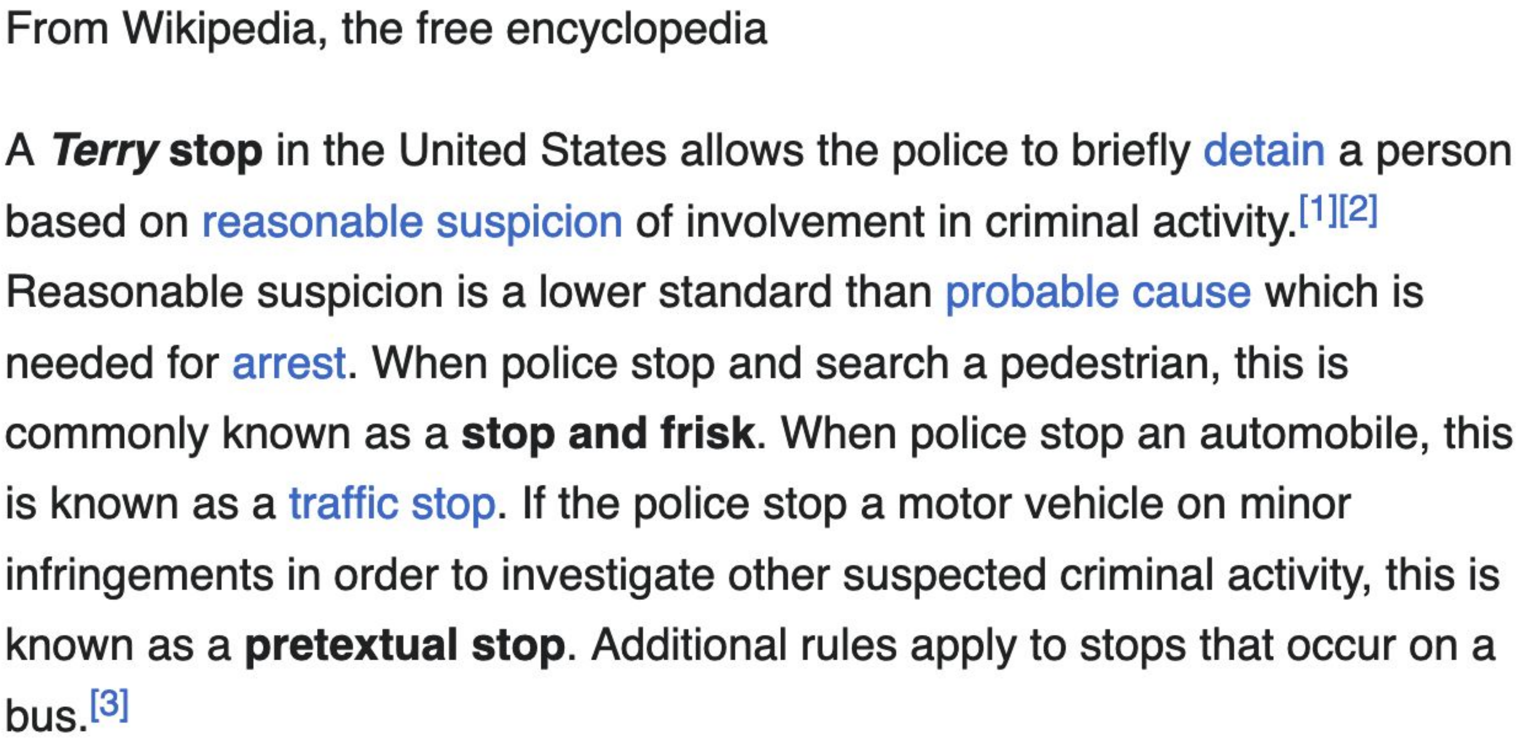
- Load Factor = # of elements stored / capacity

- A common strategy is to resize the hash map when the load factor exceeds a predefined threshold (often 0.75)
  - tradeoff between memory and runtime

HW7 Discussion

Homework 7

- NYPD “Stop Question and Frisk” dataset
- How to work with large data



From Wikipedia, the free encyclopedia

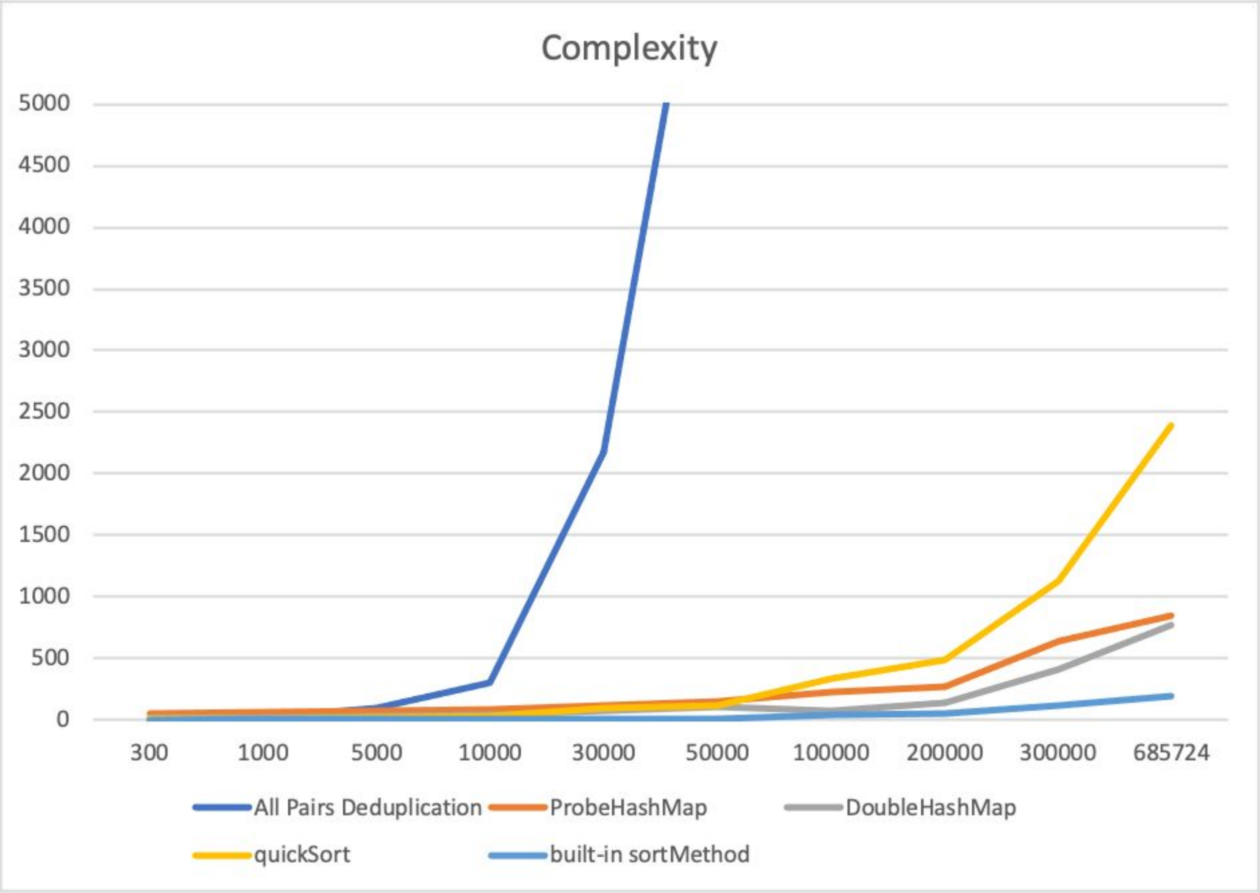
A ***Terry* stop** in the United States allows the police to briefly detain a person based on reasonable suspicion of involvement in criminal activity.[1][2] Reasonable suspicion is a lower standard than probable cause which is needed for arrest. When police stop and search a pedestrian, this is commonly known as a **stop and frisk**. When police stop an automobile, this is known as a traffic stop. If the police stop a motor vehicle on minor infringements in order to investigate other suspected criminal activity, this is known as a **pretextual stop**. Additional rules apply to stops that occur on a bus.[3]

Homework 7

- How many times was the same person stopped for questioning?

Homework 7 Part 2: Complexity Analysis

- Line graph
- x axis: number of entries
- y axis: time in seconds



Summary

ChainHashMap - handles collisions by bucketing collisions in a Linked List

ProbeHashMap - handles collisions by finding the “next” open slot

1. Linear probe
2. Quadratic probe
3. Double Hash

Chain and Probe Hash Maps have equivalent runtime complexity (Big-O notation), but Probe is faster in practice