Hash Tables: Separate Chaining

CS 124 / Department of Computer Science

What have we left out?

There are quite a few implementation details we've left out but the most important thing we've left out of our discussion so far is: what to do when hashing two di!erent keys yields the same value? This is a challenge for hash tables called "*hash collisions*" or just "*collisions.*""

We'll learn more about collisions and what to do when they occur in future lectures. It turns out there are many di!

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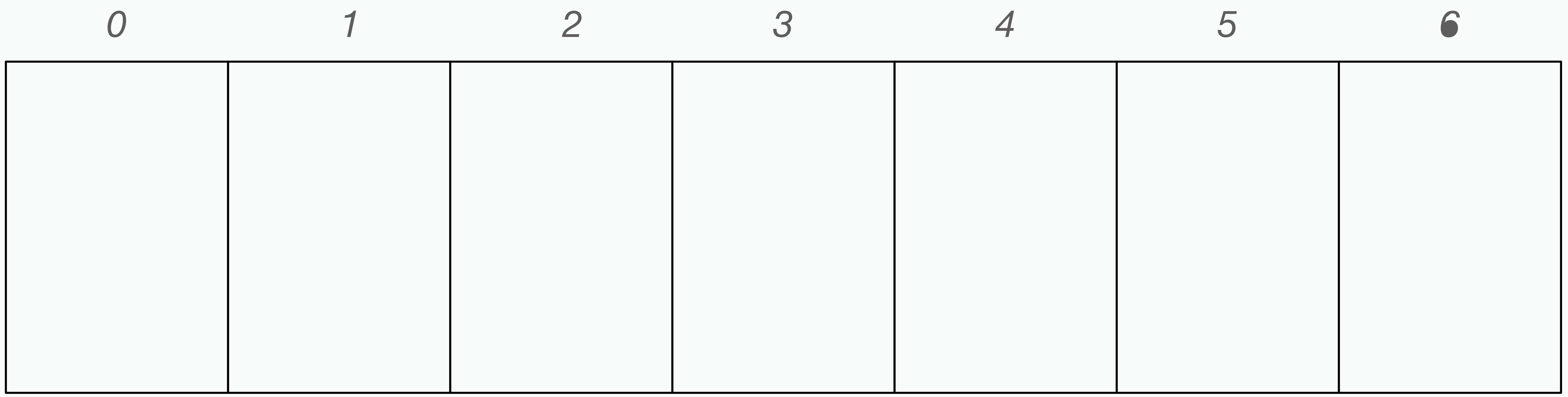
We'll learn more about collisions and what to do when they occur in future lectures. It turns out there are many di!erent strategies -- called "*collision resolution policies*," and we'll look at some of the most common ones.

Collisions are inevitable

Separate Chaining

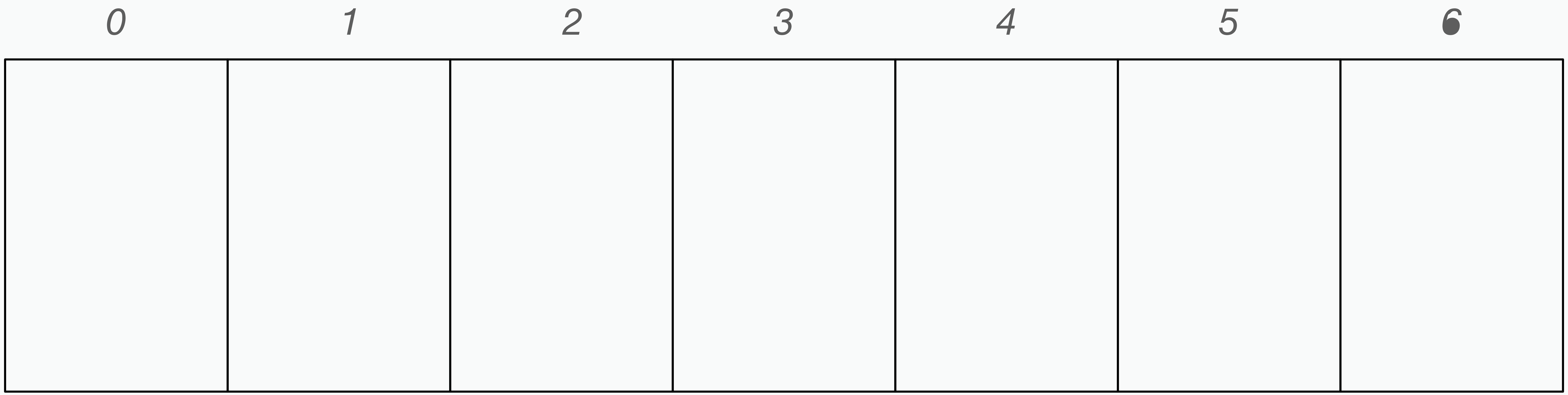
Instead of holding just one object, allow elements in our hash table to hold *more than one object*.

Separate Chaining



Separate Chaining

Hash function:#
$f(x) = x \bmod 7$



Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

13 : 13 mod 7 = 6

0	*1*	*2*	*3*	*4*	*5*	*6*

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

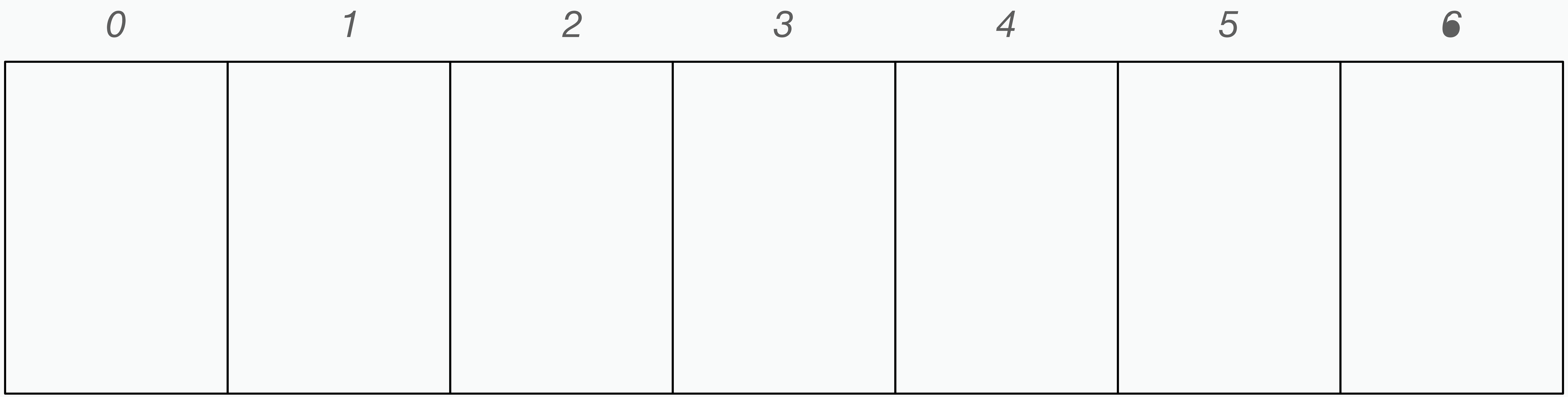
179 : 179 mod 7 = 4

0	1	2	3	4	5	6
						13

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

179 : 179 mod 7 = 4



Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

114 : 114 mod 7 = 2

0	1	2	3	4	5	6
				179		13

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

114 : 114 mod 7 = 2

0	1	2	3	4	5	6
		114		179		13

Separate Chaining

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

5 : 5 mod 7 = 5

0	1	2	3	4	5	6
		114		179	5	13

Separate Chaining

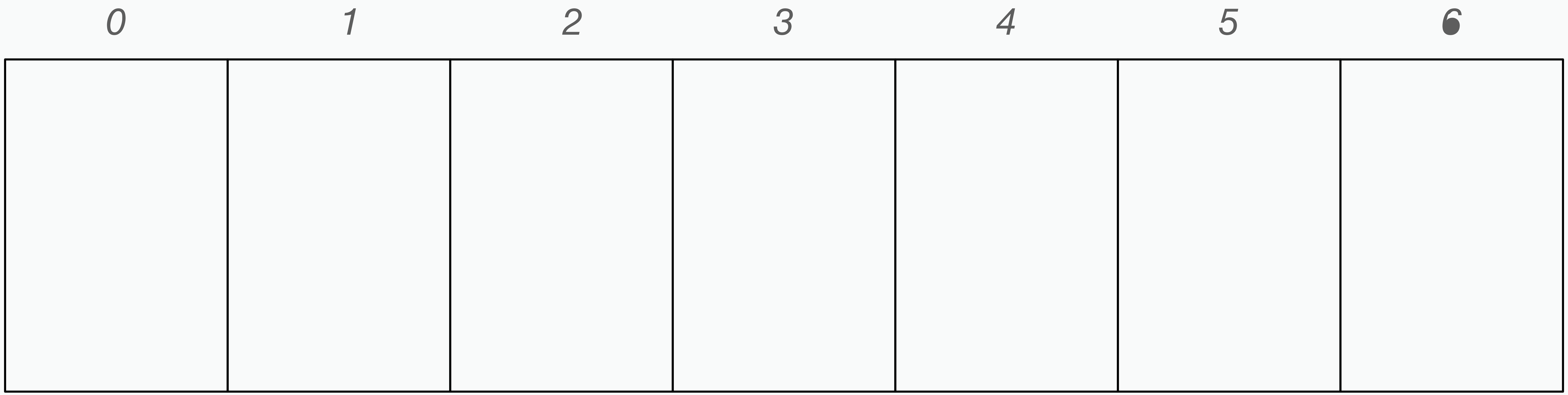
Hash function:#
$f(x) = x \bmod 7$

20 : 20 mod 7 = 6

0	1	2	3	4	5	6
		114		179	5	13

Separate Chaining

Separate Chaining



Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

73 : 73 mod 7 = 3

0	*1*	*2*	*3*	*4*	*5*	*6*
		114	73	179	5	13# 20

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

180 : 180 mod 7 = 5

0	*1*	*2*	*3*	*4*	*5*	*6*
		114	73	179	5	13# 20

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

48 : 48 mod 7 = 6

0	1	2	3	4	5	6
		114	73	179	5# 180	13# 20

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

48 : 48 mod 7 = 6

0	1	2	3	4	5	6
		114	73	179	5# 180	13# 20# 48

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

46 : 46 mod 7 = 4

0	1	2	3	4	5	6
		114	73	179	5# 180	13# 20# 48

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

46 : 46 mod 7 = 4

0	1	2	3	4	5	6
		114	73	179# 46	5# 180	13# 20# 48

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

88 : 88 mod 7 = 4

0	1	2	3	4	5	6
		114	73	179# 46	5# 180	13# 20# 48

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

88 : 88 mod 7 = 4

0	1	2	3	4	5	6
		114	73	179# 46# 88	5# 180	13# 20# 48

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

196 : 196 mod 7 = 0

0	1	2	3	4	5	6
		114	73	179# 46# 88	5# 180	13# 20# 48

Separate Chaining

Hash function:#
$f(x) = x \bmod 7$

196 : 196 mod 7 = 0

0	1	2	3	4	5	6
196		114	73	179# 46# 88	5# 180	13# 20# 48

Separate Chaining

Insertion takes constant time"

$ Calculating hash takes constant time"

$ Inserting into vector takes constant time"

But what about duplicate values?"

What about find and remove?

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What about find and remove?

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But what about duplicate values? We have to search through the bucket."

What about find and remove? We have to search through the bucket.

Separate Chaining

If we have a table of size *b* (*b* for the number of buckets) and we have n objects we wish to store, then on average a bucket will store *n* / *b* objects."

If we use linear search to check to see if an object is already in our bucket before insertion that's *O* (*n* / *b*).

Separate Chaining

If we have a table of size *b* (*b* for the number of buckets) and we have n objects we wish to store, then on average a bucket will store *n* / *b* objects."

If we use linear search to check to see if an object is already in our bucket before insertion that's O (*n* / *b*). "

We also have to search through a bucket when finding or removing."

Note that the book uses a linked list for buckets; here we're using vectors. But this doesn't change the fact that in either case we still need to search.

Summary

$ Separate chaining uses a vector of vectors (or a vector of linked lists) to handle collisions."

$ Objects with the same index calculated from the hash function wind up in the same bucket (again, whether it's a vector or linked list)."

$ This requires us to search on each insertion, find, or remove operation."

$ Separate chaining is easy to implement.

Questions

- If we sorted our buckets, we could improve search time to $O(\log(n / b))$ using binary search or $O(\log \log(n / b))$ using interpolation search. Does it make sense to do this? Why or why not?"

- Can you think of other ways we might handle collisions that don't require the use of buckets?