Hash tables

Johan Montelius

KTH

HT23

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- A linked list : ok, but $O(n)$ lookup operation.
- A sorted tree : much better, $O(lg(n))$ operations (add and lookup).
- A sorted array : binary search gives us $O(lg(n))$ lookup, but ...

zip code data base

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A file containing: zip code, name and population.

```
111 15,STOCKHOLM              ,3
111 20,STOCKHOLM              ,50
111 21,STOCKHOLM              ,344
111 22,STOCKHOLM              ,149
 :
 :
```

An array of nodes

```
pubic class Zip {
  Node[] data;

  private class Node {
    String code;
    String name;
    Integer pop;
    :
  }
  :
```

zip codes are ordered

```
public Zip(String file) {

  data = new Node[10000];
    :

  data[i++] = new Node(row[0], row[1], Integer.valueOf(row
    :
}
```

binary search

```
public String binary(String zip) {
   int mn = 0;
   int mx = max;

   while (true) {
     int index = (mn + mx)/2;

     int cmp zip.compareTo(data[index].code);

     if (cmp == 0) {
       return data[index].name;
     }
     :
   }
   return null;
 }
```

use zip code as index

```
public Zip(String file) {

   data = new Node[100000];
   :

   Integer key = Integer.valueOf(row[0].replaceAll("\\s","

   data[key] = new Node(key, row[1], Integer.valueOf(row[2
   :
 }
```

perfect ....

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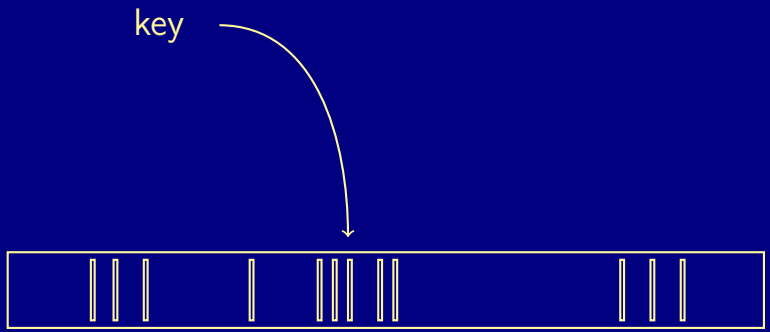
- $O(1)$ lookup

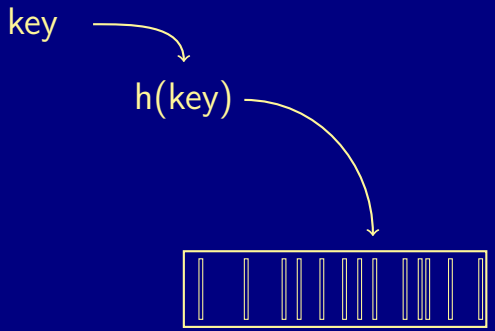
perfect ....

- $O(1)$ lookup
- what's the problem?

using key as index



the hash function



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- Keys are evenly distributed over the range of indices.
- The range $0..k$ is *resonable* (?) small.
- *Few* (?) keys map to the same index.

example of hash function

```
public static int hash(Integer key, int M) {
  return key % M;
}
```

how about a string

how about a string

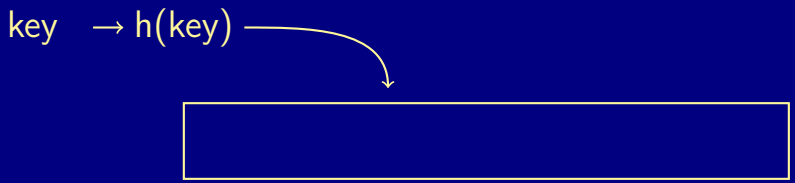
```
int R = 31;

public static Integer hash(String key, int M) {

    char[] chars = key.toCharArray();

    int value = 0;
    for (int i = 0; i < chars.length; i++) {
        value = (R * value + chars[i]) % M;
    }
    return value;
}
```

collisions

collisions

What should we do if we have collisions?

buckets



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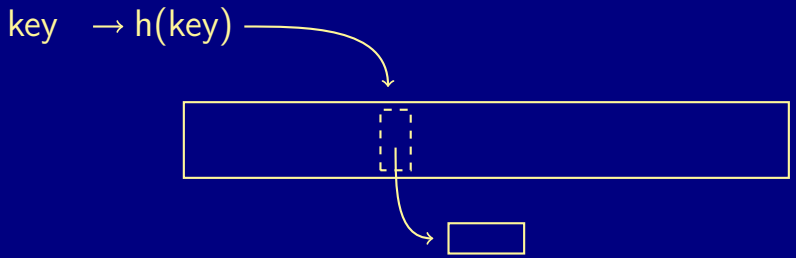

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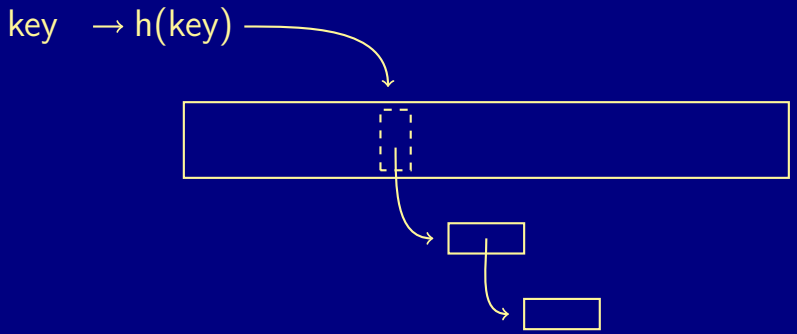

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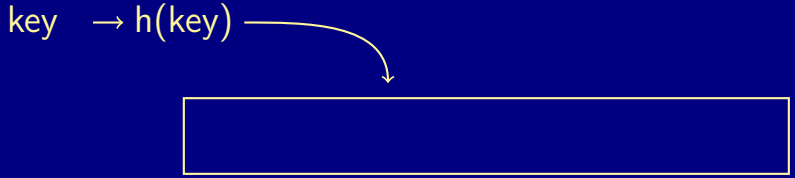
We need to search for the item.

linear probing



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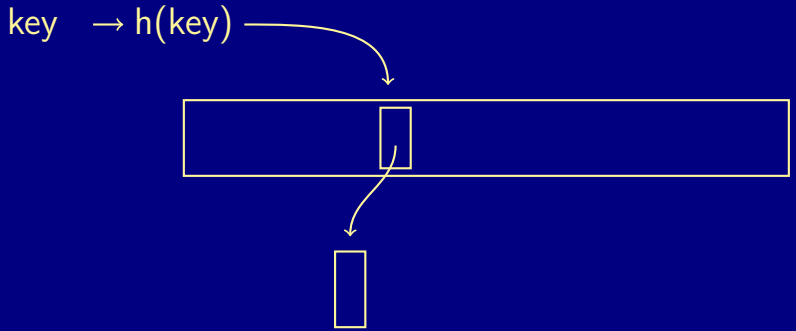

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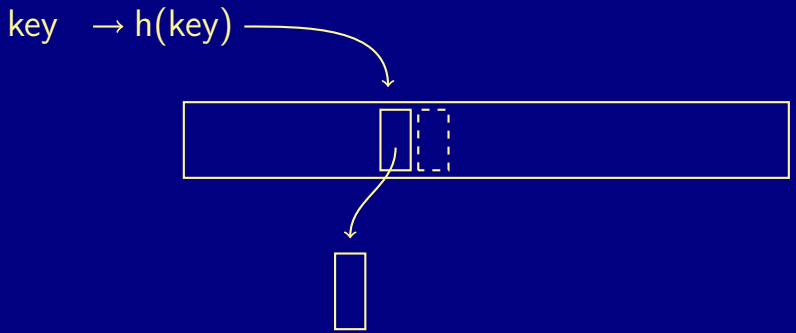

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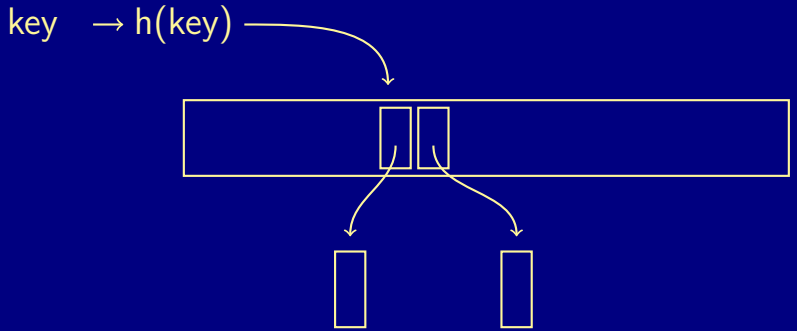
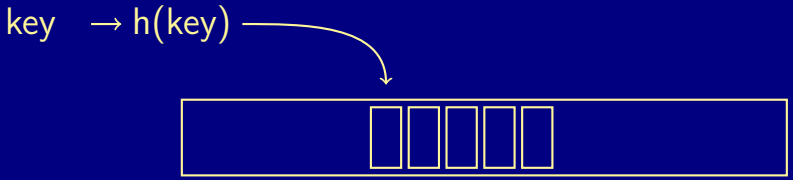


clustering



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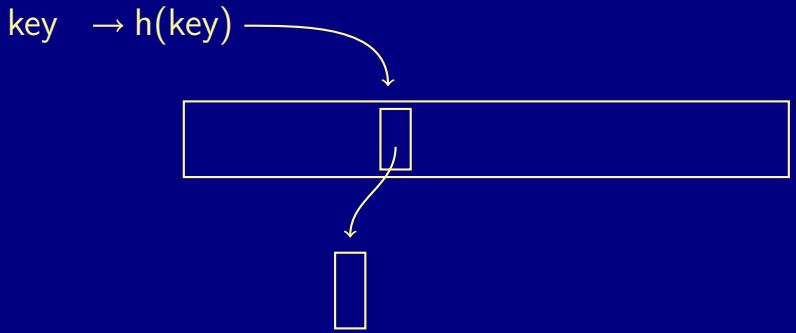

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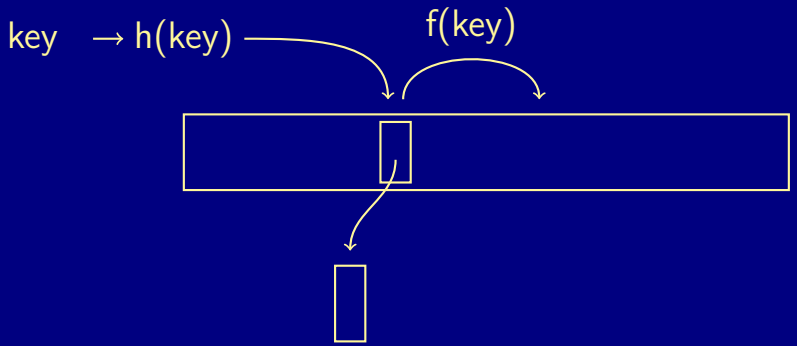

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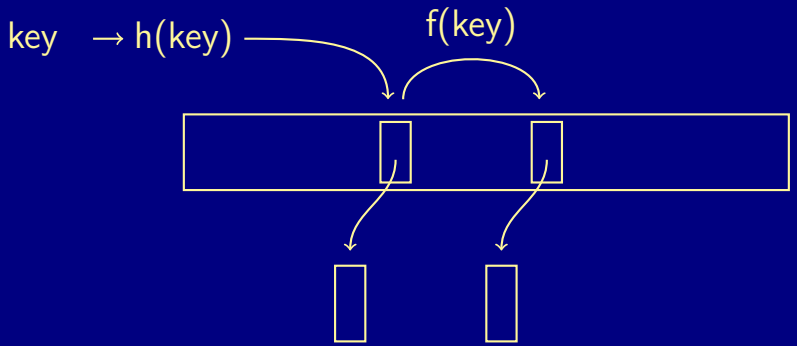

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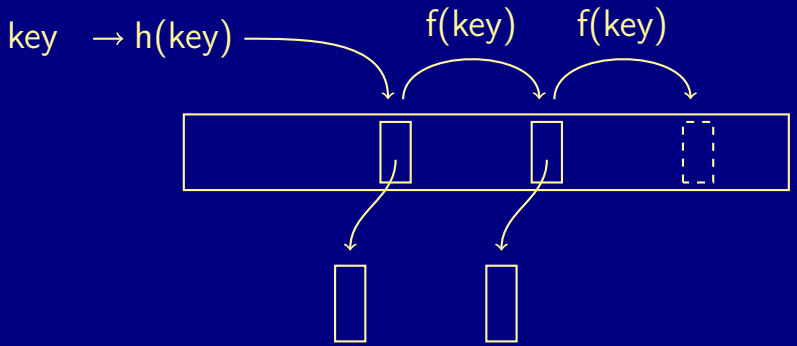

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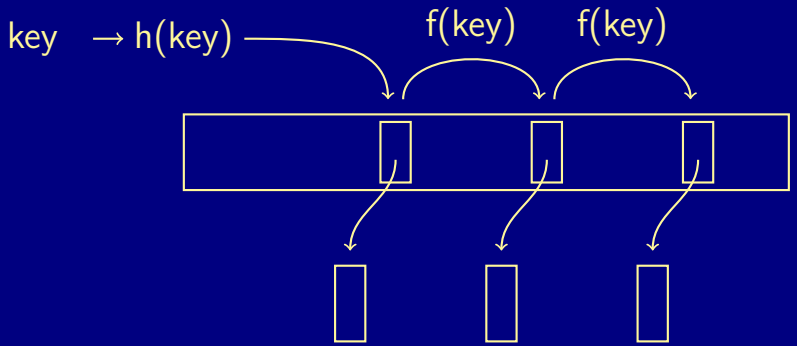

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what about remove

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- buckets: not a problem

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- buckets: not a problem
- open adressing: .... problem

R.I.P

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Replace removed key/values with a tombstone.

increase the size

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In a dynamic array we simply copied everything to a larger array ... problem?

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Computing a chryptographic hash is more expensive.