Lecture 25: Maps & Dictionaries

CS 62

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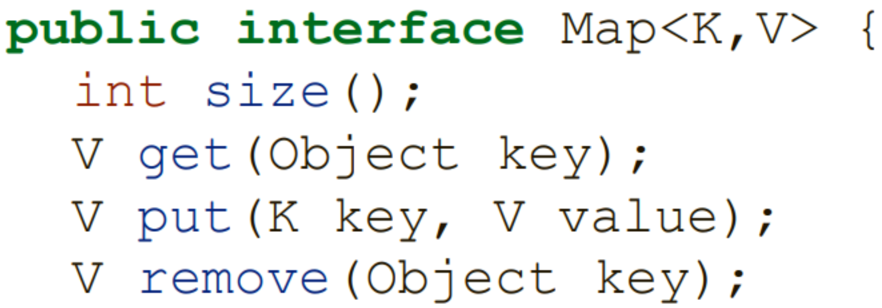
Map ADT

- Collection of associations between a key and associated value
- Store and retrieve data based on a key.
  - Store phone numbers by name.
  - Store word pair frequencies by first word.
  - Store account info by user ID.
- Cannot contain duplicate keys; at most one value per key (matches the mathematical concept).
- Also known as “dictionaries”, “symbol tables” or “associative arrays”.

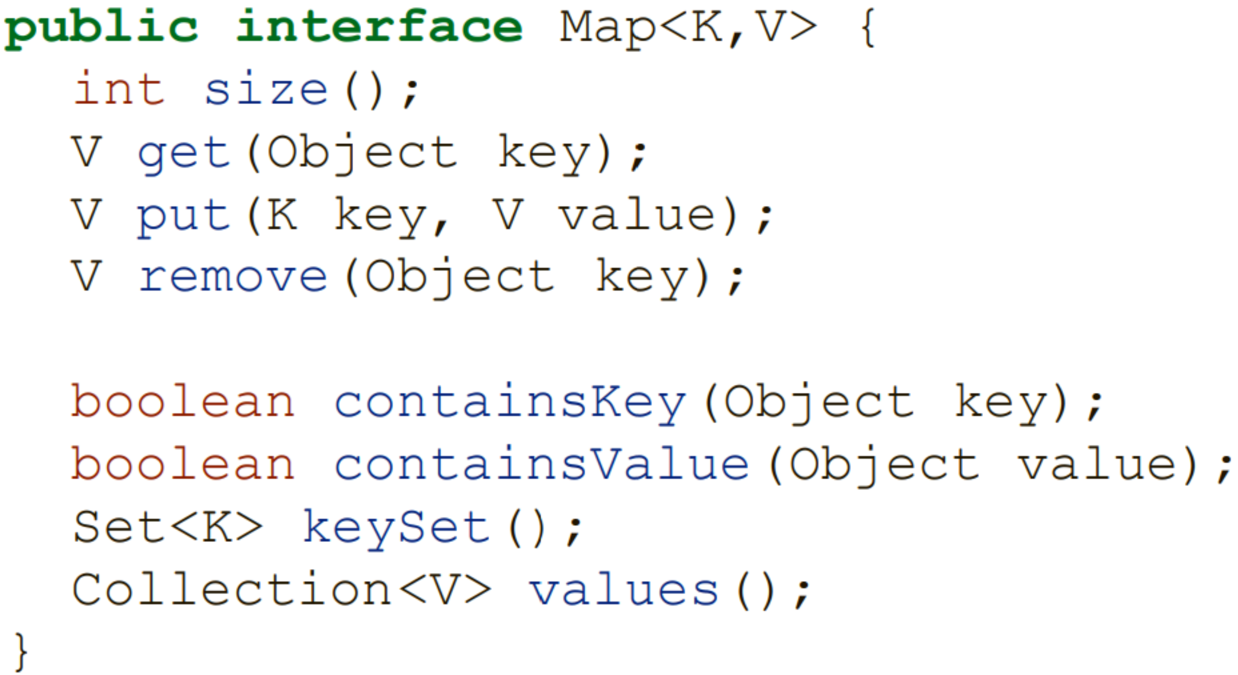
Interface



```
public interface Map<K,V> {
  int size();
  V get(Object key);
  V put(K key, V value);
  V remove(Object key);
```

- `size`: number of `(key,value)` pairs in map
- `put`: a new (`key,value`) pair in map. Return value replaced if key already exists or `null` .
- `get`: returns the corresponding value (or `null`) given a key
  - To distinguish `null` (no pair with such key was foun) from `null` ((`key,null`) pair), use `containsKey`

Interface



```
public interface Map<K,V> {
   int size();
   V get(Object key);
   V put(K key, V value);
   V remove(Object key);

   boolean containsKey(Object key);
   boolean containsValue(Object value);
   Set<K> keySet();
   Collection<V> values();
}
```

Map Implementations

Data Structure	get	put	remove
List	$O(n)$	$O(n)$	$O(n)$
Sorted list	$O(logn)$	$O(n)$	$O(n)$
Balanced BST	$O(logn)$	$O(logn)$	$O(logn)$
Array[“key range”]	$O(1)$	$O(1)$	$O(1)$

Last row is array where keys are subscripts

`http://bigocheatsheet.com/`

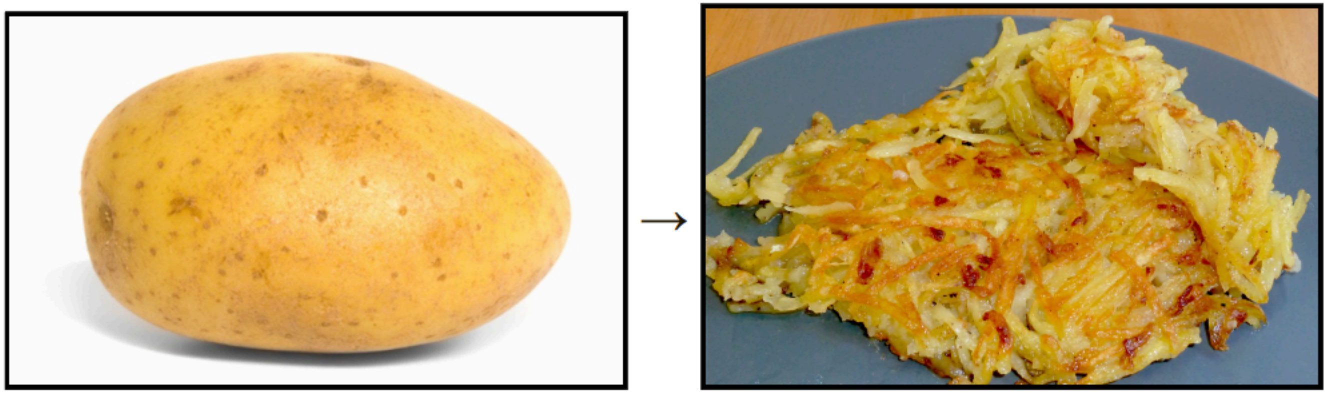
Problem

- Goal: Array-like performance for all keys

- Problems:
  - Keys are not integers
    (and there is no obvious way to convert them)

  - Key range may be large or infinite
    (and keys may be sparse)
    - Suppose use SS#'s as subscripts to table of students

Hashing

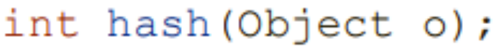


Map data of arbitrary size (keys) to data of fixed size (indices)

HashMaps

- Array-like implementations of maps that provide $O(1)$ lookup
- Components:
  - Hash table: array of “buckets”
  - Hash function: to compute index of bucket
- Value returned by hash function: hash code, hash value, or hash
- Typically, number of keys is larger than table size
- Ideally, hash function will assign each key to a unique bucket
- In practice, non-perfect hash functions which cause collisions
- Value returned is called hash code, hash value, or hash

Perfect Hashing



```
int hash(Object o);
```

- Should be $O(1)$.
- Should return an integer.
- The integers for our n keys should be $0 \ldots n\text{-}1$.
- Must be a unique integer for every object.
  - That is, it should be injective.
- Given hash, just use an array where: items[H(key)] = value
- So important that hashCode function built-in to Java classes.

Hash Functions

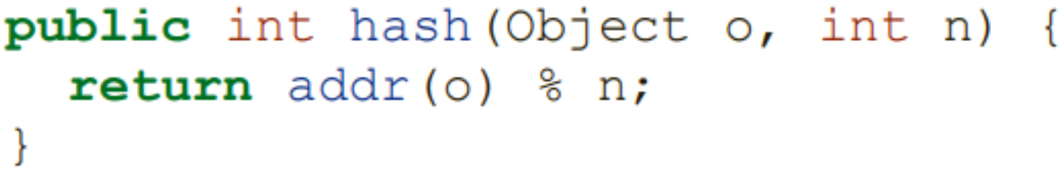
- Look for reasonable function that scatters elements through array randomly so won't bump into each other.
- Lose any ordering on keys
- Ideal is to find in time $O(1)$.
- We want to:
  - Find good hashing functions
  - Figure out what to do if 2 elements are sent to same location

- *"A given hash function must always be tried on real data in order to find out whether it is effective or not."*

Actual Hashing

- Unique integer for an `Object`?
  Its address in memory.

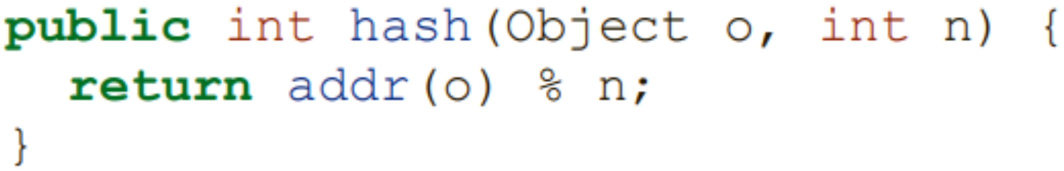
- Numbers in $0 \ldots n\text{-}1$?
  Take the modulus by n



```
public int hash(Object o, int n) {
  return addr(o) % n;
}
```

Actual Hashing

- ✓ Should be O(1)
- ✓ Should return an integer.
- ✓ The integers for our n keys should be 0 … n-1.
- X Must be a unique integer for every object.
  (true in the limit as $n \rightarrow \infty$)

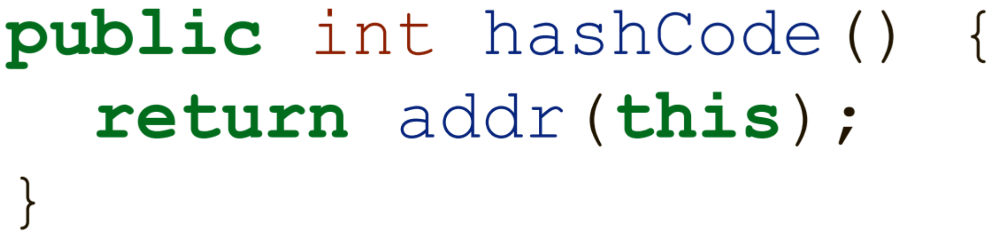


```
public int hash(Object o, int n) {
  return addr(o) % n;
}
```

Actual Hashing

- Call `obj.hashCode` instead of `hash(obj)`

- Let each map object do the modulus (n is different)



```
public int hashCode() {
   return addr(this);
}
```

Handling and Equality

```
public class Point {
  public int x, y;

  public boolean equals(Object other) {
    if (other instanceof Point) {
      return (this.x == other.x
           && this.y == other.y);
    }
    return false;
  }

  public int hashCode() { return addr(this); }
}
```

Problems

- What to do when results aren’t unique?
- What about objects with `.equals`?
- How can we get a good distribution of results?