Lecture 29: Maps & Hashing

Fall 2016

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Midterm #2

- In class next Friday, 11-31
- Will cover material through parallelism
- Questions will focus on material since midterm #1:
  - Array representations of trees
  - Heaps & Heapsort
  - Binary search trees
  - Balanced binary search trees
  - Parallelism
  - Concurrency

Hackathon!

- Announcement near the end of class today.

Darwin Contest Results

Section 1

Student:	**Survivors:**	**Percentage:**
Dylan Keezell	60514 / 72800	83.1%
Julian DeGroot-Lutzner	42853 / 72800	58.9%
Rex Bodoia	35229 / 72800	48.4%

Honorable Mention:

Victor deFontnouvelle (47.5%), Brady DeMeritt (47.4%), Wentao Guo (45.6%)

Darwin Contest Results

Section 2

Student:	Survivors:	Percentage:
Somtochukwu Uzoegwu	89798 / 108800	82.5%
Dominic Frempong	89348 / 108800	82.1%
Claire Genre	65386 / 108800	60.1%

Honorable mention:

Victor Machado (59.5%), Eberto Ruiz (58.3%), Brook Solomon (57.1%)

Maps

- 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.
- At most one value per key (matches the mathematical concept).
- Also known as "dictionaries" or "hash tables."

Interface

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




}
```

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();
}
```

Implementations

Data Structure	`get`	`set`	`remove`
list	O(n)	O(1)	O(n)
sorted list	O(log n)	O(n)	O(n)
balanced BST	O(log n)	O(log n)	O(log n)
array[“key range”]	O(1)	O(1)	O(1)

http://bigocheatsheet.com/

Implementations

“Peter Mawhorter” → “pmawhorter”
“Kim Bruce” → “kim”

- What if keys aren’t integers?
- What if we don’t know the keys ahead of time?

~~fixed array~~

Can we do better than a balanced binary search tree?

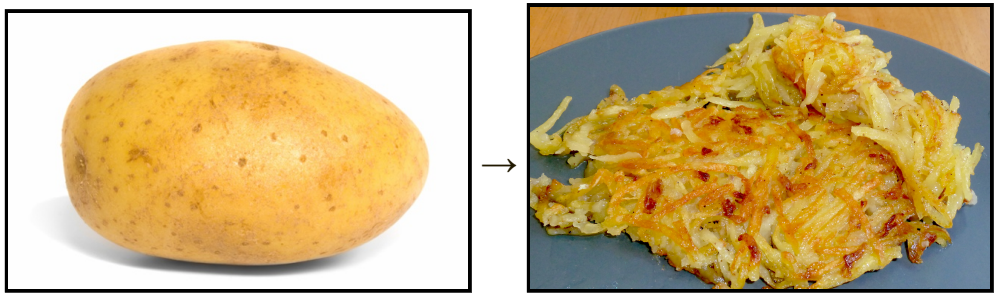
Problem

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)

Hashing



Perfect Hashing

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

- Should be O(1).
- Should return an integer.
- The integers for our N keys should be 0 … N-1.
- Must be a unique integer for every object.
  - That is, it should be *bijective*.

Given `hash`, just use an array where:

```
items[H(key)] = value
```

Actual Hashing

- Unique integer for an `Object`?
  Its address in memory.
- Numbers in 0 … N-1?
  Take the modulus by N.

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

Actual Hashing

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

✓ Should be O(1).
✓ Should return an integer.
✓ The integers for our N keys should be 0 … N-1.
✗ Must be a unique integer for every object.
(true in the limit as N → ∞)

Actual Hashing

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

- Call `obj.hashCode` instead of `hash(obj)`
- Let each map object do the modulus (N is different)

Hashing 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?