Compsci 201
Collections, Hashing, Objects
Glitchy App?

Faulty Iowa App Was Part of Push to Restore Democrats’ Digital Edge

The App That Crashed the Iowa Caucuses

What led to the breakdown of the Iowa caucus app?
Glitchy App?

Shadow, Inc. (@ShadowIncHQ)

We sincerely regret the delay in the reporting of the results of last night’s Iowa caucuses and the uncertainty it has caused to the candidates, their campaigns, and Democratic caucus-goers.
H is for …

- Hashing
  - What better way to have a bucket list?

- Hexadecimal
  - ABC is 10, 11, 12
  - Base 16 > Base 2?
Announcements

• Assignment P2 out later this week
• APT-3 due Tues, Feb 4, Extended to Thurs Feb 6
  • Last chance to turn in Friday til 11:59pm
• Discussion 5 on Feb 10
  • Prepare for exam
• Exam next week, Feb 14
• Interfaces: List, Set, and Map
  • When it makes sense to use general type
  • Empirical and Analytical measures of efficiency

• Maps: API and Problem Solving
  • Keys and Values

• Big-Oh and O-Notation
  • Building a mathematical formalism with intuition
Midterm Coming Feb 14

• How much code have you written with paper and a writing utensil?
  • Tests should measure what you've practiced
  • Practice writing code on paper!

• Midterm review and previous tests
  • These are the best practice available
  • Will practice in Discussion

• Logistics
  • Start on time, end on time, accommodations
  • 1 page front and back of notes you bring and leave
Breakfast 201 was yummy!

- Wed. Feb 5 9:30am
- 30 minutes, discuss whatever with me
- Enjoy breakfast
- More breakfasts coming!
The hashCode contract

• Every object has `.hashCode()` method
  • Inherited from Object, but typically overridden
  • Use @Override and read online

• Must respect `.equals()`: If `a.equals(b)` ?
  • `a.hashCode() == b.hashCode()`
  • Converse not true! There will be collisions
When Strings Collide

- Generate strings that will collide
- Find such strings in the wild

<table>
<thead>
<tr>
<th>String</th>
<th>hashCode</th>
</tr>
</thead>
<tbody>
<tr>
<td>ayay</td>
<td>3009136</td>
</tr>
<tr>
<td>ayBZ</td>
<td>3009136</td>
</tr>
<tr>
<td>bZay</td>
<td>3009136</td>
</tr>
<tr>
<td>bZbZ</td>
<td>3009136</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>String</th>
<th>hashCode</th>
</tr>
</thead>
<tbody>
<tr>
<td>buzzards</td>
<td>-931102253</td>
</tr>
<tr>
<td>righto</td>
<td>-931102253</td>
</tr>
<tr>
<td>snitz</td>
<td>109586548</td>
</tr>
<tr>
<td>unprecludible</td>
<td>109586548</td>
</tr>
</tbody>
</table>
Default: Object.equals, .hashCode
When you do not override...

• For Objects p and q:
  • p.equals(q) is the same as p == q
  • Do p and q reference/point to same object

• For Object p
  • p.hashCode() is location in memory of object

• Thus: if p == q then
  • p.hashCode() == q.hashCode()
Default: `Object.equals`, `.hashCode`

When you do not override…

- For Objects `p` and `q`:
  - `p.equals(q)` is the same as `p == q`
  - `p` and `q` reference/point to same object

- For Object `p`:
  - `p.hashCode()` is location in memory of object

- Thus, if `p == q` then:
  - `p.hashCode() == q.hashCode()`
Summary: ArrayList and HashSet

- Both have `.add`, `.addAll`, and more
  - Both iterable: `for(Elt e : collection)`

- Both have `.contains` leveraging `.equals`
  - HashSet also uses `.hashCode` to reduce the collection iterated over: locker collisions

- Object hygiene when developing your classes
  - `.toString()`, `.equals()`, `.hashCode()`
When Strings Collide

https://www.youtube.com/watch?v=HeTShE2PiQI
When Strings Collide

- Generate strings that will collide
- Find such strings in the wild

<table>
<thead>
<tr>
<th>String</th>
<th>hashCode</th>
</tr>
</thead>
<tbody>
<tr>
<td>ayay</td>
<td>3009136</td>
</tr>
<tr>
<td>ayBZ</td>
<td>3009136</td>
</tr>
<tr>
<td>bZay</td>
<td>3009136</td>
</tr>
<tr>
<td>bZbZ</td>
<td>3009136</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>String</th>
<th>hashCode</th>
</tr>
</thead>
<tbody>
<tr>
<td>buzzards</td>
<td>-931102253</td>
</tr>
<tr>
<td>righto</td>
<td>-931102253</td>
</tr>
<tr>
<td>snitz</td>
<td>109586548</td>
</tr>
<tr>
<td>unprecludible</td>
<td>109586548</td>
</tr>
</tbody>
</table>
Concept: Inheritance

- In Java, every class extends Object
  - Gets methods by default: .toString, .hashCode, .equals, and more
  - Inherit method + implementation
- Subclass can override base class methods
  - Make .equals work for Point class
Work in 201

• How important are APTs?
  • How important are APT quizzes?

• How important are assignments?
  • Earlier assignments, later assignments?

• How important: reading and WOTO in-class
  • How important is reading?
Alphabetical Order

• Encryption? Maybe not
  • [https://www2.cs.duke.edu/csed/newapt/encryption.html](https://www2.cs.duke.edu/csed/newapt/encryption.html)
  • Think about high-level algorithm
  • Apply your algorithm to: "pop", "array", "deeds"

• What do we need to do to code algorithm?
  • Recall: 'b' + 1 == 'c'
  • Recall: array['h'] is allowed, 'h' can be index
Idea with Encryption APT

```java
int[] allchars = new int[256];
int nextLet = 'a';

message is feed
answer is
ch is
```

<table>
<thead>
<tr>
<th>ASCII</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>'a'</td>
</tr>
<tr>
<td>97</td>
<td>'b'</td>
</tr>
<tr>
<td>98</td>
<td>'c'</td>
</tr>
<tr>
<td>99</td>
<td>'d'</td>
</tr>
<tr>
<td>100</td>
<td>'e'</td>
</tr>
<tr>
<td>101</td>
<td>'f'</td>
</tr>
<tr>
<td>102</td>
<td>'g'</td>
</tr>
</tbody>
</table>

2/5/2020 CompSci 201, Spring 2020
Idea with Encryption APT

Iterate over chars in message

int[] allchars = new int[256];
int nextLet is 'a'

message is feed

answer is

ch is
Idea with Encryption APT

Iterate over chars in message

int[] allchars = new int[256];
int nextLet is 'a'

message is feed
answer is “a”
ch is ‘f’
Idea with Encryption APT

Update nextLet

int[] allchars = new int[256];
int nextLet = 'b'

message is feed
answer is “a”

ch is ‘f’
Idea with Encryption APT

**Process next character**

```java
int[] allchars = new int[256];
int nextLet is ‘b’

message is feed
answer is “a”

ch is ‘e’
```
Idea with Encryption APT

Process next character

```java
int[] allchars = new int[256];

int nextLet = 'b';

String answer = "";

message is feed

answer is "a"

ch is 'e'

96 0
97 0 'a'
98 0 'b'
99 0 'c'
100 0 'd'
101 0 'e'
102 'a' 'f'
103 0 'g'
```
Idea with Encryption APT

**Update answer**

```java
int[] allchars = new int[256];
int nextLet is 'b'

message is feed
answer is “ab”

ch is ‘e’
```

```
96  0
97  0  ‘a’
98  0  ‘b’
99  0  ‘c’
100 0  ‘d’
101 ‘b’ ‘e’
102 ‘a’ ‘f’
103 0  ‘g’
```
Idea with Encryption APT

Update nextLet

```java
int[] allchars = new int[256];
int nextLet = 'c';

message is feed
answer is “ab”
ch is ‘e’
```

<table>
<thead>
<tr>
<th>ASCII</th>
<th>Value</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>0</td>
<td>‘a’</td>
</tr>
<tr>
<td>97</td>
<td>0</td>
<td>‘b’</td>
</tr>
<tr>
<td>98</td>
<td>0</td>
<td>‘c’</td>
</tr>
<tr>
<td>99</td>
<td>0</td>
<td>‘d’</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>‘e’</td>
</tr>
<tr>
<td>101</td>
<td>0</td>
<td>‘f’</td>
</tr>
<tr>
<td>102</td>
<td>0</td>
<td>‘g’</td>
</tr>
</tbody>
</table>
Idea with Encryption APT

Process next character

```java
int[] allchars = new int[256];
int nextLet = 'c';

message is feed
answer is “ab”
ch is ‘e’
```

<table>
<thead>
<tr>
<th>ASCII</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>0</td>
</tr>
<tr>
<td>97</td>
<td>0</td>
</tr>
<tr>
<td>98</td>
<td>0</td>
</tr>
<tr>
<td>99</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>101</td>
<td>0</td>
</tr>
<tr>
<td>102</td>
<td>0</td>
</tr>
<tr>
<td>103</td>
<td>0</td>
</tr>
</tbody>
</table>

'abcdfg'
Idea with Encryption APT

‘e’ already has a value, use it

```java
int[] allchars = new int[256];
int nextLet is ‘c’

message is feed
answer is “ab”

ch is ‘e’
```

<table>
<thead>
<tr>
<th>ASCII Code</th>
<th>Value</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>0</td>
<td>‘a’</td>
</tr>
<tr>
<td>97</td>
<td>0</td>
<td>‘b’</td>
</tr>
<tr>
<td>98</td>
<td>0</td>
<td>‘c’</td>
</tr>
<tr>
<td>99</td>
<td>0</td>
<td>‘d’</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>‘e’</td>
</tr>
<tr>
<td>101</td>
<td>‘b’</td>
<td>‘f’</td>
</tr>
<tr>
<td>102</td>
<td>‘a’</td>
<td>‘g’</td>
</tr>
</tbody>
</table>

2/5/2020
CompSci 201, Spring 2020
Idea with Encryption APT

Update answer

int[] allchars = new int[256];
int nextLet is 'c'

message is feed
answer is “abb”

ch is ‘e’
Idea with Encryption APT

*Don’t update nextLet*

```java
int[] allchars = new int[256];

int nextLet is ‘c’

message is feed

answer is “abb”

ch is ‘e’
```

<table>
<thead>
<tr>
<th>Index</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>0</td>
</tr>
<tr>
<td>97</td>
<td>‘a’</td>
</tr>
<tr>
<td>98</td>
<td>‘b’</td>
</tr>
<tr>
<td>99</td>
<td>‘c’</td>
</tr>
<tr>
<td>100</td>
<td>‘d’</td>
</tr>
<tr>
<td>101</td>
<td>‘e’</td>
</tr>
<tr>
<td>102</td>
<td>‘f’</td>
</tr>
<tr>
<td>103</td>
<td>‘g’</td>
</tr>
</tbody>
</table>
Idea with Encryption APT

Process next character

```java
int[] allchars = new int[256];
int nextLet is ‘c’

message is feed
answer is “abb”
ch is ‘d’
```

<table>
<thead>
<tr>
<th>ASCII Code</th>
<th>Value</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>0</td>
<td>‘a’</td>
</tr>
<tr>
<td>97</td>
<td>0</td>
<td>‘b’</td>
</tr>
<tr>
<td>98</td>
<td>0</td>
<td>‘c’</td>
</tr>
<tr>
<td>99</td>
<td>0</td>
<td>‘d’</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td>‘e’</td>
</tr>
<tr>
<td>101</td>
<td>‘b’</td>
<td>‘f’</td>
</tr>
<tr>
<td>102</td>
<td>‘a’</td>
<td>‘g’</td>
</tr>
</tbody>
</table>

2/5/2020
CompSci 201, Spring 2020
Idea with Encryption APT

Process next character

```java
int[] allchars = new int[256];

int nextLet = 'c';

message is "feed"

answer is "abb"

ch is 'd'
```
Idea with Encryption APT

Update answer

```java
int[] allchars = new int[256];
int nextLet = 'c';

message is feed
answer is “abbc”

ch is ‘d’
```
Idea with Encryption APT

Word translated, Update nextLet

```java
int[] allchars = new int[256];
int nextLet is ‘d’

message is feed
answer is “abbc”

ch is
```

<table>
<thead>
<tr>
<th>ASCII Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>0</td>
</tr>
<tr>
<td>97</td>
<td>0</td>
</tr>
<tr>
<td>98</td>
<td>0</td>
</tr>
<tr>
<td>99</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>‘c’</td>
</tr>
<tr>
<td>101</td>
<td>‘b’</td>
</tr>
<tr>
<td>102</td>
<td>‘a’</td>
</tr>
<tr>
<td>103</td>
<td>0</td>
</tr>
</tbody>
</table>
How often does a string occur?

- Strings stored in ArrayList?
  - Call `Collections.frequency(list, word)`
  - If in array `a` rather than ArrayList?
    `Collections.frequency(Arrays.asList(a), word)`

```java
ArrayList<String> list is
[“cat”, “cat”, “dog”, “fish”, “dog”, “cat”]
```

```java
Collections.frequency(list, “dog”) is
Collections.frequency(list, “cat”) is
```
How often does a string occur?

• Strings stored in ArrayList?
  • Call
    Collections.frequency(list, word)
  • If in array a rather than ArrayList?
    Collections.frequency(Arrays.asList(a), word)

ArrayList<String> list is
[“cat”, “cat”, “dog”, “fish”, “dog”, “cat”]

Collections.frequency(list, “dog”) is 2
Collections.frequency(list, “cat”) is 3
How often does a string occur?

• Is Collections.frequency efficient? Does it matter?
  • Use Collections.frequency
  • Can create parallel arrays or use HashMap
    • Keep \texttt{count[k]} \# occurrences of \texttt{word[k]}
  • Use HashMap if you know that
WOTO (correctness counts)

Shafi Goldwasser

- 2012 Turing Award Winner
- RCS professor of computer science at MIT
  - Twice Godel Prize winner
  - Grace Murray Hopper Award
  - National Academy
  - Co-inventor of zero-knowledge proof protocols

*Work on what you like, what feels right, I know of no other way to end up doing creative work*
Why use an interface?
Why use an interface?

**HDMI**

**Bluetooth**

**RESTful API**

**Application Programming Interface**
What is a Java Interface?

• An enforceable abstraction: methods required
  • Set, Map, List interfaces

• Can implement more than one interface
  • Can extend only one base-class!

• Arguable: Mammal is an interface
  • *Do NOT inherit* method implementations
  • Do inherit methods (names, types, etc.)
Analogy: Mammals

• Dragon?

• Mammals
Analogy: Mammals

• Dragon?

• Mammals
  • Birth to live young
  • Hair
  • Warm-blooded

• Like an interface!
Why use an Interface?

• Work with frameworks, e.g., java.util.Collection
  • Iterable, Serializable, and more – use with Java

• ArrayList, LinkedList, TreeSet, HashSet all …
  • .clear(), .contains(o),
    .addAll(..), .size(), … .toArray()
There are two kinds ...

• There are 10 kinds of people in the world ...
  • Those who understand binary and ...
  • Is this funny?

• HashSet/HashMap and TreeSet/TreeMap
  • Tradeoffs in efficiency, organization

• LinkedList/ArrayList
  • Tradeoffs in efficiency, organization
Link v Array

• Getting between two elements
  • Unsnap/Snap v Shift/Insert
Preliminaries

- `List<..>` is an interface in `java.util`
  - `LinkedList<..>` and `ArrayList<..>`
  - Implement the interface

- What is null?
  - Variable value
  - No object referenced
Benchmark: Empirical Analysis

- [https://coursework.cs.duke.edu/201spring20/classcode/](https://coursework.cs.duke.edu/201spring20/classcode/)
- In class ListSplicer, method removeFirst
  - `List<String>` parameter
  - `ArrayList<String>` argument passed
  - `LinkedList<String>` argument passed

- Only call `List<..>` interface methods
  - At runtime, call the actual object method
  - `LinkedList.add` or `ArrayList.add`
list.remove(0)

- What is “faster”? LinkedList or ArrayList

```java
public double removeFirst(List<String> list) {
    double start = System.nanoTime();
    while (list.size() != 1) {
        list.remove(0);
    }
    double end = System.nanoTime();
    return (end - start) / 1e9;
}
```
list.remove(0) – where called

```
first = 100000;
last = 1500000;
incr = 100000;
for (int k = first; k <= last; k += incr) {
    List<String> linked = new LinkedList<>();
    List<String> array = new ArrayList<>();
    linked = splicer.create(linked, k);
    array = splicer.create(array, k);
    List<String> lcopy = new LinkedList(linked);
    List<String> acopy = new ArrayList(array);
    System.gc();
    double ltime = splicer.removeFirst(linked);
    double atime = splicer.removeFirst(array);
```
list.remove(0)

- What is “faster”? LinkedList or ArrayList
Access all elements randomly

• What is “faster”? LinkedList or ArrayList

```java
public double randomAccess(List<String> list) {
    ArrayList<Integer> nums = new ArrayList<>();
    for (int k = 0; k < list.size(); k += 1) {
        nums.add(k);
    }

    Random rand = new Random(SEED);
    Collections.shuffle(nums, rand);
    double start = System.nanoTime();
    for (int index : nums) {
        String dummy = list.get(index);
        String shadow = dummy;
        if (shadow == dummy) continue;
    }
    double end = System.nanoTime();
    return (end - start) / 1e9;
}
```
Access all elements randomly

- What is “faster”? LinkedList or ArrayList

![Random Access Graph]

\[ \begin{align*}
\text{Linked} & : y = 0.1292x^2 - 0.7137x + 1.3337, R^2 = 0.9889 \\
\text{Array} & : y = 0.0002x + 5E-05, R^2 = 0.8169
\end{align*} \]