CS 225
Data Structures

Nov. 1 – Hashing 3
Running Times

The expected number of probes for find(key) under SUHA

**Linear Probing:**
- Successful: \( \frac{1}{2} \left( 1 + \frac{1}{1 - \alpha} \right) \)
- Unsuccessful: \( \frac{1}{2} \left( 1 + \frac{1}{1 - \alpha} \right)^2 \)

**Double Hashing:**
- Successful: \( \frac{1}{\alpha} \times \ln(\frac{1}{1 - \alpha}) \)
- Unsuccessful: \( \frac{1}{1 - \alpha} \)
ReHashing

What if the array fills?
## Running Times

<table>
<thead>
<tr>
<th></th>
<th>Hash Table</th>
<th>AVL</th>
<th>Linked List</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Find</strong></td>
<td>Amortized:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worst Case:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Insert</strong></td>
<td>Amortized:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worst Case:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Storage Space</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Which collision resolution strategy is better?
• Big Records:

• Structure Speed:

What structure do hash tables replace?

What constraint exists on hashing that doesn’t exist with BSTs?

Why talk about BSTs at all?
std data structures

std::map
std data structures

**std::map**
- `::operator[]`
- `::insert`
- `::erase`

- `::lower_bound(key)` ➔ Iterator to first element ≤ key
- `::upper_bound(key)` ➔ Iterator to first element > key
std data structures

std::unordered_map
    ::operator[]
    ::insert
    ::erase

    ::lower_bound(key) → Iterator to first element ≤ key
    ::upper_bound(key) → Iterator to first element > key
std data structures

std::unordered_map
::operator[]
::insert
::erase

::lower_bound(key) → Iterator to first element ≤ key
::upper_bound(key) → Iterator to first element > key

::load_factor()
::max_load_factor(ml) → Sets the max load factor
CS 225’s Final Exam

Exam Details:
CBTF Exam, 3 Hours Long
Theory (MCQ) and Programming Questions
When you finish your exam, you’re done with CS 225! :)

Signup Process:
CS 225 Exam will run Thursday, Dec. 14 - Monday, Dec. 18
(including both Saturday and Sunday)

You can sign up for your slot starting tomorrow at 9:00am.
Secret, Mystery Data Structure

ADT:
- insert
- remove
- isEmpty
## Priority Queue Implementation

<table>
<thead>
<tr>
<th></th>
<th><strong>insert</strong></th>
<th><strong>removeMin</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>O(n)</td>
<td>O(n)</td>
<td>O(n)</td>
</tr>
<tr>
<td>O(1)</td>
<td>O(n)</td>
<td>O(1)</td>
</tr>
<tr>
<td>O(lg(n))</td>
<td>O(1)</td>
<td>O(lg(n))</td>
</tr>
<tr>
<td>O(lg(n))</td>
<td>O(1)</td>
<td>O(lg(n))</td>
</tr>
</tbody>
</table>
A New Tree Structure

```
4
  /   \
 /     \
5      6
  |     |
15     7
     /   |
   16   9  20
      /     |
     25 14 12
        /   |
       11
```
(min)Heap
Register for CS 225’s Final Exam!

Exam 8 (programming exam, MP4-like and AVL) is live!
More Info: https://courses.engr.illinois.edu/cs225/fa2017/exams/

MP5: kd-trees
Due Monday, Nov. 6 at 11:59pm

Lab: lab_hash released today
Due Sunday, Nov. 5 at 11:59pm

POTD
Every Monday-Friday – Worth +1 Extra Credit /problem (up to +40 total)