CSE 326: Data Structures
Priority Queues

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Today's Outline

- Introduction to Trees
- Priority Queues
- Heaps

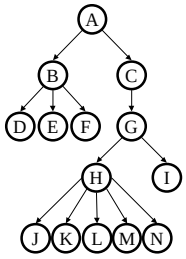
} Chapter 6 in Weiss

Trees

- Family Trees
- Organization Charts
- Classification trees
  - what kind of flower is this?
  - is this mushroom poisonous?
- File directory structure
  - folders, subfolders in Windows
  - directories, subdirectories in UNIX or WWW

Tree Terminology

root:
leaf:
child:
parent:
sibling:
ancestor:
descendent:
subtree:

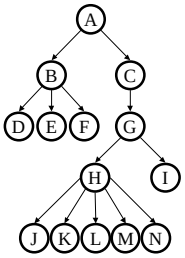


More Tree Terminology

depth:

height:

branching factor:



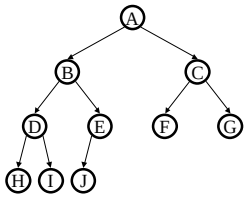
One More Tree Terminology Slide

binary:

n-ary:

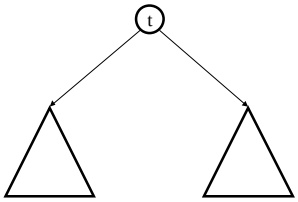
complete:

size???



Tree Calculations

Find the height of the tree...



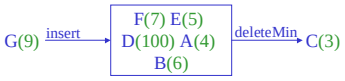
Back to Queues

- Some applications
  - ordering CPU jobs
  - simulating events
  - picking the next search site
- Problems?
  - short jobs **should go first**
  - earliest (simulated time) events **should go first**
  - most promising sites **should be searched first**

Remember ADTs?

Priority Queue ADT

- Priority Queue operations
  - insert
  - deleteMin
  - is_empty



- Priority Queue property: for two elements in the queue, *x* and *y*, if *x* has a lower priority value than *y*, *x* will be deleted before *y*

Applications of the Priority Q

- Hold jobs for a printer in order of length
- Store packets on network routers in order of urgency
- Order web search results by the "rank" of the web page
- Sort numbers
- Anything *greedy*

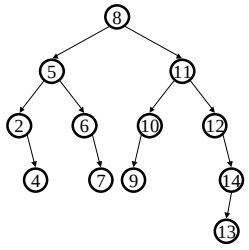
Naïve Priority Q Data Structures

- Unsorted list:
  - *insert:*
  - *deleteMin:*
- Sorted list:
  - *insert:*
  - *deleteMin:*

Binary Search Tree Priority Q Data Structure (that's a mouthful)

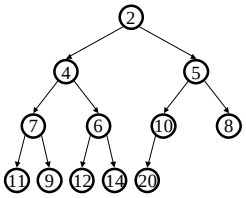
insert:

deleteMin:



Binary Heap Priority Q Data Structure

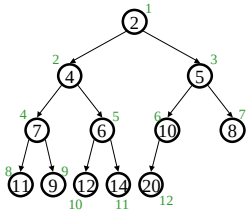
- Structure property
  - complete binary tree (fringe nodes packed to the left)
  - result: depth is always O(log n); next open location always known
- Heap-order property
  - parent's key is less than children's keys
  - result: minimum is always at the top



How do we find the minimum?

Array Implementation

- Calculations...
  - left child:
  - right child:
  - parent:
  - root:
  - next free:

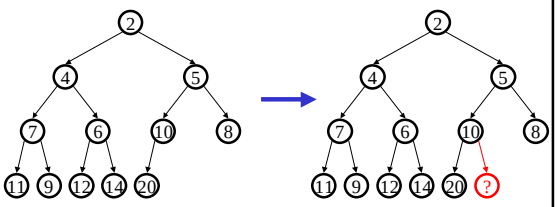


size

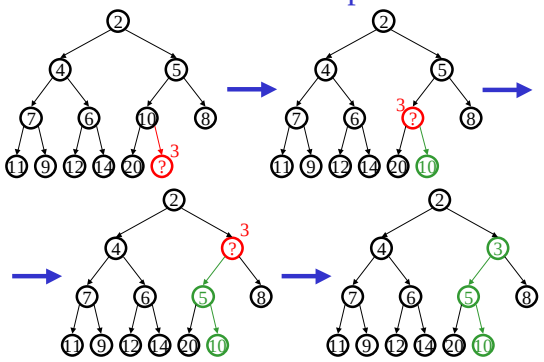
0	1	2	3	4	5	6	7	8	9	10	11	12
12	2	4	5	7	6	10	8	11	9	12	14	20

Insert

`pqueue.insert(3)`



Percolate Up



Insert Code

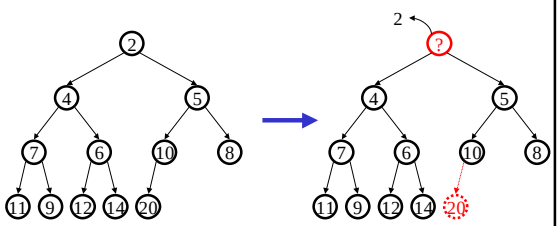
```
void insert(Object o) {
  // Heap cannot be full!
  size++; // Heap[0]++;
  newPos =
    percolateUp(size,o);
  Heap[newPos] = o;
}
```

```
int percolateUp(int hole,
                Object val) {
  while (hole > 1 &&
         val < Heap[hole/2])
    Heap[hole] = Heap[hole/2];
    hole /= 2;
  }
  return hole;
}
```

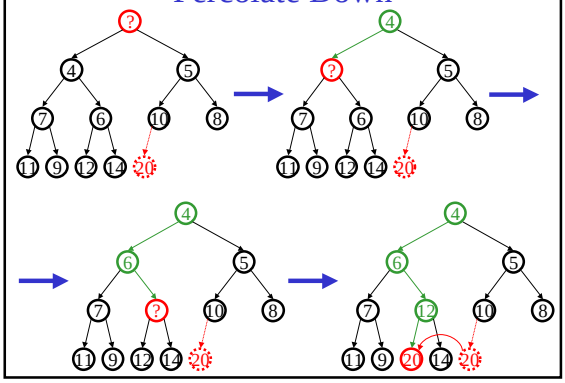
runtime:

DeleteMin

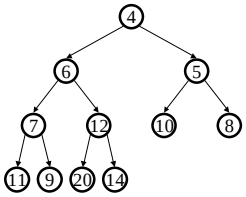
`pqueue.deleteMin()`



Percolate Down



Finally…



DeleteMin Code

```
Object deleteMin() {
  // Heap cannot be empty
  returnVal = Heap[1];
  size--; // Heap[0]--;
  newPos =
    percolateDown(1,
        Heap[size+1]);
  Heap[newPos] =
    Heap[size + 1];
  return returnVal;
}
```

runtime:

```
int percolateDown(int hole,
                  Object val) {
while (2*hole <= size) {
    left = 2*hole;
    right = left + 1;
    if (right <= size &&
        Heap[right] < Heap[left])
      target = right;
    else
      target = left;

    if (Heap[target] < val) {
      Heap[hole] = Heap[target];
      hole = target;
    }
    else
      break;
  }
  return hole;
}
```

Coming Up

- Leftist heaps
- Skew heaps
- *d*-heaps

- No section on July 4!!!