CS 61B Midterm 1 Notes

Jeffrey Shen

Pointers

- Passes a pointer to array as parameter for a method
- pass by value: primitive types

Classes / Inheritance

- Always implicit call to Superclass constructor from subclass
- Dynamic method selection

Compile Time	Runtime
Static	Dynamic
1) Choose method, throw error if not found	2) Find exact signature match in subclasses

Variable	Static	Dynamic
d	Dog	Corgi
c	Corgi	Corgi

- Remember to use Package Name for public class if using from another package (ex) Pl. Cl x = new ....)

Access Modifiers

Modifier	Class	Package	Subclass	Global
public	✓	✓	✓	✓
protected	✓	✓	✓	X
package private (default)	✓	✓	X	X
private	✓	X	X	X

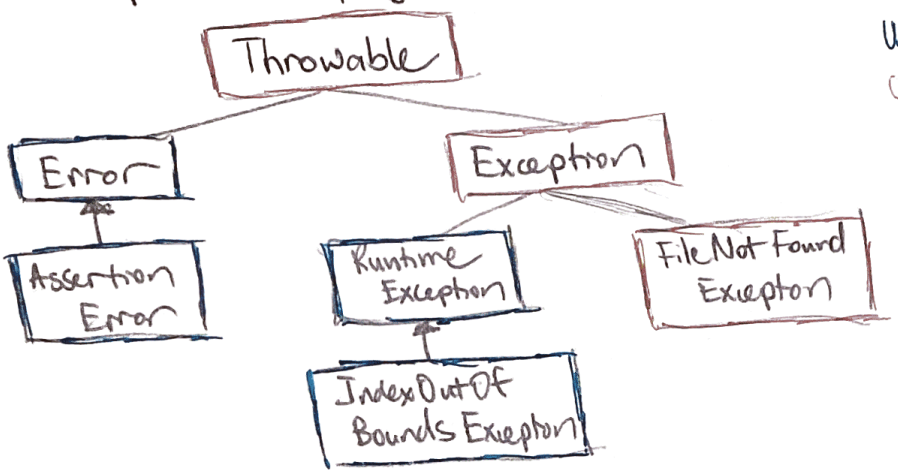
- Available anywhere
- Available within subclasses outside package
- Available within same package
- Available only within same class

- static methods cannot be overridden
- Overriding: Same method signature in subclass
- Overloading: Same method name but different numbers or types of arguments
- Static belong to class, non-static belongs to instance

Exceptions

Ex) "throw new IllegalArgumentException();"
try { //code } catch (SomeException e) { //code };

- Checked Exceptions: non-programmer errors declared in method header
- Unchecked Exceptions: programmer errors



Unit Testing

Ex) assertArrayEquals(int[] expected, int[] actual)
assertEquals(double expected, double actual, double delta)

Interfaces : implements

```
public interface Comparable<T> {
    int compareTo(T x);
} // whether this <,=,> x
```

```
public interface Iterable<T> {
    Iterator<T> iterator();
}
```

```
public interface Comparator<T> {
    int compare(T o1, T o2);
    boolean equals(Object obj);
}
```

```
public interface Iterator<E> {
    boolean hasNext();
    E next();
}
```

Tips

- Check variable types and return, indexes
- go back and check numbers after filling outline
- Int List for loops

Ex) for (p.tail = null, p = result; p.tail != null; p = p.tail) {

CS 61B Midterm 2 Notes — Jeffrey Shen

Integers

Type	Bits	Signed
byte	8	Yes
short	16	Yes
char	16	No
int	32	Yes
long	64	Yes

Bit Twidding

			Input	Use
Mask	&	"and"	2	Mod (last digits (n-1)
Set	|	"or"	2	Add
Flip	^	"not equal"	2	Unequal bits
Flip all	~	"not"	1	
Shift Left	<<	shift left, falls off		Multiply
Arithmetic Right	>>	Brings sign bit		} Divide
Logical Right	>>>	Starts with 0		

Complexity

1) Consider Worst Case
2) Pick proxy for overall runtime
3) Ignore lower order terms
4) Ignore multiplicative constants

Big Theta	$\Theta(N)$	Same order of growth
Big O	$O(N)$	Upper bounded by N
Big Omega	$\Omega(N)$	Lower bounded by N

Collections Interface

List: Indexed sequences w/ duplication (ex. ArrayList, LinkedList)
Set, SortedSet: Collections w/o duplication (ex. HashSet, TreeSet)
Map, SortedMap: Dictionaries, key value pairs (ex. HashMap, TreeMap)

Time Complexities

Avg Time [Worst Time]

Data Structure	Access	Search	Insertion	Deletion
Array	$\Theta(1)$	$\Theta(n)$	$\Theta(n)$	$\Theta(n)$
Stack / Queue / Linked List	$\Theta(n)$	$\Theta(n)$	$\Theta(1)$	$\Theta(1)$
Hash Table	N/A	$\Theta(1)$ [$O(n)$]	$\Theta(1)$ [$O(n)$]	$\Theta(1)$ [$O(n)$]
BST / Heaps	$\Theta(\log n)$ [$O(n)$]	$\Theta(\log n)$ [$O(n)$]	$\Theta(\log n)$ [$O(n)$]	$\Theta(\log n)$ [$O(n)$]

Inserting n elements with $\log n$ time each becomes $n \log n$

$\Theta(n)$: $n, \frac{n}{2}, \frac{n}{4}, \ldots$ ($\log n$ terms)

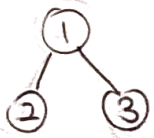
$\Theta(n \log n)$: n, $\frac{n}{2}, \frac{n}{2}$, $\frac{n}{4}, \frac{n}{4}, \frac{n}{4}, \frac{n}{4}$ ($\log n$ terms)

$\Theta(n \log n)$: $1, 2, 4, 8, \ldots$ (n terms)

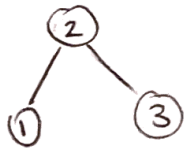
Trees

Inorder on a BST will give sorted list

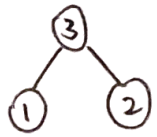
Preorder



In order



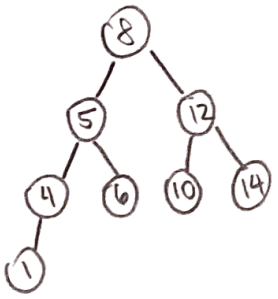
Post Order



Depth First: Stack (LIFO)

Breadth-First: Queue (FIFO)
(Level-Order) ⇉

Binary Search Tree (BST)



- Nodes in left subtree have smaller keys
- Nodes in right subtree have larger keys

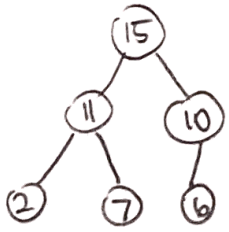
Insertion: Search for node, input where should be

Deletion: Find smallest number in right side and replace

Game Trees

- Assign heuristic to board, node is position, edge is move
- I choose max value, opponent chooses min val
- Alpha-beta pruning: prune as we search, sends down values that are acceptable and discontinues if not in range

Heaps



- Min/Max Heap: Labels of both children are less/greater than node

Insert: Put at next available on bottom row, bubble up

Remove: Swap with element in bottom right, bubble down

Change: Find node, bubble up or down

Hashing

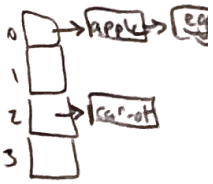
Convert key to bucket number using hash funct

Avoid collisions: keys that hash to equal values, Valid if hash func is same for same keys

Load Factor: N(items)/M(buckets) = L

Resize when Load factor > some value, resize table, rehash all items

Add, lookup, deletion: O(1) but can't find largest/smallest



Pattern Matching, Regular Expressions (RegEx)

Character class ([0-9abd-qs-z])
- Any of the single characters

Wildcard (.)
- Period can match any character

Compliment, Not ([^abe])
- Matches any single character other than those listed

Character Class shortcut (\s, \d)
\s - whitespace \d - [0-9] need to use "\\d" to get \key

Repetitions (*, +, ?)
P* - "0 or more repitions of P"
P+ - "1 or more Ps"
P? - "0 or 1 Ps"

Or (P|Q)
- Either "P" or "Q"

Group ((P))
- Subpattern to reference later

Escape (\?, *, \., \+)
- Need to use two-character escape sequences to match (\?)

Exam Tips

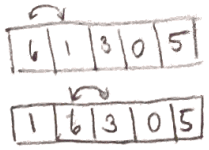
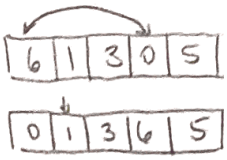
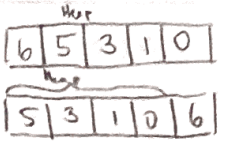
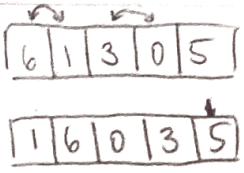
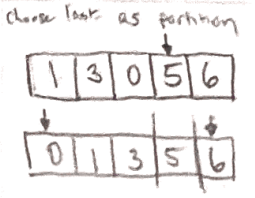
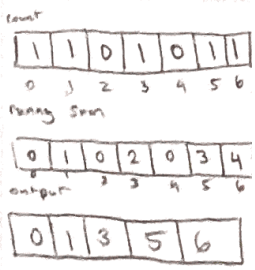
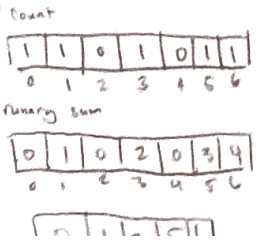
- Pay attention to object types
- Remember case where input is null
- Don't forget capital and lowercase RegEx, edge cases
- Linked List in HashMap takes linear time to add, (check for repeat)

CS 61B Final Notes

Jeffrey Shen

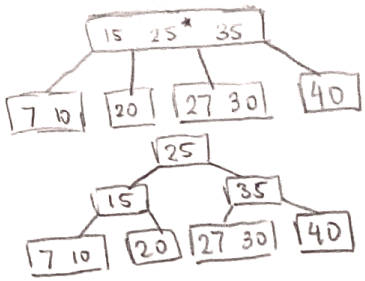
LSD/MSD → Selection → Heap → Quick → Merge → Insertion

Sorts

Sort	Description	Runtime Avg [Worst]	Stable	Diagram
Insertion Sort	- Add each item from unsorted sequence, insert into ordered subsequence > for i=1 to n-1 while arr[i] < arr[i-1] swap(i,i-1) - Good for small data sets or almost ordered	$\Theta(kN)$ $[O(N^2)]$ where k is # of inversions	Y	
Selection Sort	- Repeatedly finding min element and placing in front >for i=0 to n-1 for i to n-1 find min element swap(min,i)	$\Theta(N^2)$	N	
Heap sort	- Sort into max heap and keep selecting largest > for i=n/2-1 to 0 heapify for i=n-1 to 0 swap(0,i) heapify 0 to i	$\Theta(N \log N)$ Best: $\Theta(N)$	N	
Merge Sort	- Divide data into equal parts, recursively sort halves, merge results > sort(int[] arr, int l, int r){ if l<r sort(arr, 0, middle) sort(arr, middle, r) merge(arr, l, m, r)	$\Theta(N \log N)$	Y	
Quicksort	- Partition data into pieces everything > pivot at high everything < pivot on low end - Can do insertion sort when partition is small enough > quicksort(arr[], low, high) if low < high partitionIndex = partition(arr, low, high) quicksort(arr, low, pi-1) quicksort(arr, pi, high)	$\Theta(N \log N)$ $[O(N^2)]$ if choosing bad partitions	N	
Distribution Counting	- put integers into N buckets of counts then have running sum of indexes, then insert into final array > for i=0 to n count[arr[i]]++ set up count array for i=0 to K count[i] += count[i-1] set up running sum for i=n-1 to 0 output[count[arr[i]]-1] = arr[i] copy to output count[arr[i]]--	$\Theta(N+K)$ where K is range of input	Y	
Radix Sort (LSD, MSD) Least, Most Significant Digit	- Sort keys one at a time - Good for small keys >for each digit: for i=0 to n count[arr[i]%10]++; count digit for i=0 to 10 count[i] += count[i-1] running sum for i=n-1 to 0	$\Theta(B)$ When B is # bytes, size of key data	Y	

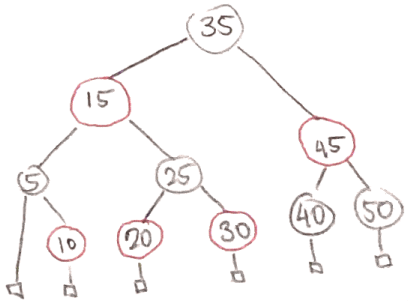
Balanced Search Structures - want to maintain bushy trees to perform fast operations

B-Trees Ex) 2-3 trees, 2-4 or 2,3,4 trees



Order M B-tree has max of M children for node and max of M-1 elements per node, follows BST structure w/ left nodes smaller than element and right nodes larger. If overfill, move one node up and split.

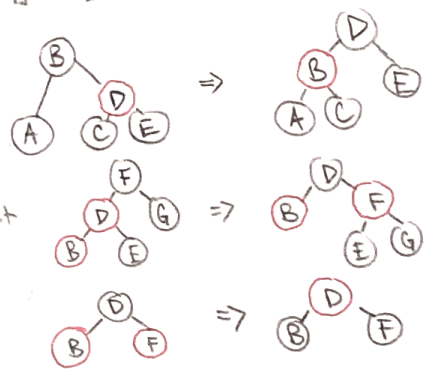
Red-Black Tree (Left-Leaning Red Black Trees)



- Representation of B tree that is easier to implement
- Properties:
  1) root is black
  2) Every leaf node has no data and is black
  3) Every leaf has same number of black ancestors
  4) Every internal node has two children
  5) Every red node has two black children

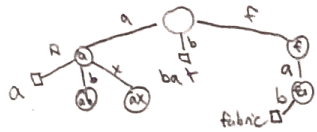
> Insert as red node in correct place

- Fixup tree:
  1) Convert right-leaning to left-leaning
     > right().isRed() and left().isBlack()? rotate left
  2) Rotate linked red nodes into normal 4 node
     > left().isRed() and left().left().isRed()? rotate right
  3) Break up 4 nodes into 3 nodes or 2nodes
     > left().isRed() and right().isRed()? colorFlip(tree)
  4) Turn root black after fixups



Trie

- Each internal node coorespords to letter, posible prefix
- Can use DataIndexedCharMap, Bushy BST, or Hash Table
- use for prefix can combine with pronty Queue for autocomplete



Skip Lists

- Search tree where we choose to put keys at "random" heights
- Start at top layer, search until next step would overshoot, go down one layer and repeat

Performance

B-Trees / Red-Black Trees

$\Theta(\log N)$

searches, insertions, deletions

Tries

$\Theta(B)$

searches, insertions, deletions

B is length of key

Skip Lists

$\Theta(\log N)$

searches, insertions, deletions

randomized

Hash functions

Cryptographic Hash Functions (function f) - are so unlikely to have collision we can ignore

- Pre-image resistance: given $h = f(m)$ computationally infeasible to find m
- Second pre-image resistance: given message m_1, infeasible to find $m_2 \neq m_1$ st $f(m_1) = f(m_2)$
- Collision resistance: difficult to find any two messages $m_1 \neq m_2$ st $f(m_1) = f(m_2)$

Ex) SHA1 160 bit hash codes of contents in hex

Graphs

Graphs have set of nodes (V) and edges (E), can be directed, cyclic or acyclic

Recursive Depth-First Traversal

Stack

- mark nodes as we traverse, don't traverse previously traversed

Preorder - mark, visit, traverse edges

```
> void preorderTraverse(Graph G, Node v){
    if v is unmarked
      mark(v)
      visit(v)
      for Edge(v,w) ∈ G
        traverse(G,w)
```

Postorder - mark, traverse edges, visit

```
> void postorderTraverse(Graph G, Node v){
    if v is unmarked
      mark(v)
      for Edge(v,w) ∈ G
        traverse(G,w)
      visit(v)
```

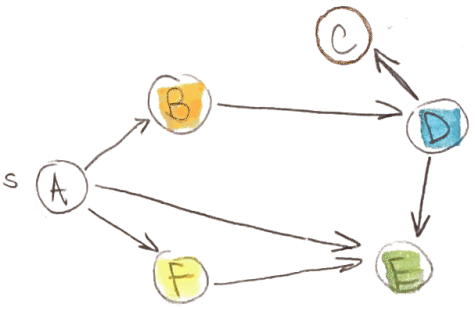
Breadth-First Traversal

- visit edges and store nodes in a queue for processing

Topological Sorting

For a Directed Acyclic Graph (DAG), find linear order of nodes where order $v_0, v_1, \ldots$ st v_k is never reachable from $v_{k'}$ if $k' > k$

Ex)



DFS preorder

DFS postorder

BFS

Topological Sort

Adjacency list

A → [D, E, F]
B → [D]
C → [ ]
D → [C, E]
E → [ ]
F → [ ]

Adjacency matrix

	A	B	C	D	E	F
A	0	1	0	0	1	1
B	0	0	0	1	0	0
C	0	0	0	0	0	0
D	0	0	1	0	1	0
E	0	0	0	0	0	0
F	0	0	0	0	1	0

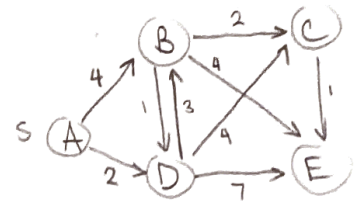
Dijkstra's Algorithm

Given weighted graph w/ non-negative weights, connected

- Find shortest paths from source vertex s to some target vertex t in weighted graph

fringe: priority queue

> fringe.add(source, 0)
for other vertices, fringe.add(v, ∞)
while fringe not empty
    Vertex v = fringe.removeSmallest()
    for each edge(v,w)
        if distTo[v] + weight(v,w) < distTo[w]
            distTo[w] = distTo[v] + weight(v,w)
            edgeTo[w] = v
            fringe.changePriority(w, distTo[w])



Node	dist	edgeTo
A	0	—
B	4	A
C	6	B
D	2	A
E	7	C

① ③ ④ ② ⑤

fringe: {A: 0, B: 4, C: 6, D: 2, E: 7}

- Visit vertices in order of best known distance, relax edges

A* search

- Want shortest path from source vertex to desired vertex
- Use heuristic guess h(v) and order by sum of distance + heuristic of remaing dist

Properties of heuristic:
1) Admissible: h(v, NYC) ≤ true distance from v to NYC
2) Consistent: for each neighbor of w:
   h(v, NYC) ≤ weight(v,w) + h(w, NYC)

Consistent ⇒ admissible

Dijkstra's vs. A*

Both: time = time to remove V nodes from priority queue, + time to update neighbors, reorder queue

$\Theta((V+E)\log V)$

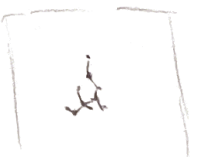
A* searches to particular target node, Dijkstra's finds shortest-path tree

Minimum Spanning Tree

- Given set of places and distances between, find set of connecting roads w/ min total length

Prim's Algorithm

- Grow tree from arbitrary node, add shortest edge connecting some node that isn't in tree
- Similar to Dijkstra's, compare weights instead of total distance
  > ∀ w ∈ fringe && weight(v,w) < w.dist()
    w.dist() = weight(v,w); v.parent = v;



Kruskal's Algorithm

- Consider edges in order of increasing weight, add unless cycle
- Use Union-Find:
  - Find what group, path to root
  - Combine two groups, point one root to other

> for each edge in increasing order of weight, if (v,w) connects different subtrees, combine