Algorithms for Interviews

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This Talk

Sequel to Data Structures for Interviews

- -This talk is more challenging
- -Assumes data structures proficiency

for each:

- -Basic Principles
- -Example Problems
- -Study Guide

Outline

Sorting

Recursion

Greedy

Dynamic Programming

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Dynamic Programming

Sorting

Given a collection of comparable elements, sort them.

Collection: Array, ArrayList, LinkedList, Stack, Queue

(Relevant) Sorting Algorithms

Slowest

$O(n^2)$	Selection Sort, Insertion Sort
$O(nlogn)$	Quicksort, Mergesort, Heapsort
$O(n)$	Bucket Sort, Radix Sort

Fastest

Lightning Review of Sorts!

Selection Sort

Repeatedly select the smallest unsorted element and place it right after the sorted elements.

$O(n^2)$

Insertion Sort

Repeatedly slide each element left until it is in the proper relative place.

$O(n^2)$

Bucket Sort

Scatter elements into buckets, sort within each bucket, and combine the buckets.

O(n)

Radix Sort

Sort within significant positions for all significant positions.

O(n)

Heapsort

Build a heap and repeatedly extract the root.

O(nlogn)

Mergesort

Repeatedly divide lists into two sublists, repeatedly merge the sublists together in sorted order.

> Recursion Tree Breakdown

O(nlogn)

Quicksort

Sort elements only with respect to a pivot such that the pivot is in its final location, Recur on left and right sublists.

> Recursion Tree Breakdown

O(nlogn)

Study Guide

Implement the nlogn sorts.

What are the best and worst case inputs for each sort?

- -Runtimes?

How do you sort a Linked List? How about a stack or queue?

- -Runtimes?
- -Space complexities?

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Recursion

Use recursion when the solution to the problem depends on solutions to smaller instances of the same problem.

> Fibonacci Recursion Tree Breakdown

```
fib(0) = 1
fib(1) = 1
fib(n) = fib(n-2) + fib(n-1)      for n>1
```

Divide and Conquer

Dividing a problem into subproblems that are solved recursively and then combined to solve the original problem.

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Dividing a problem into subproblems that are solved recursively and then combined to solve the original problem.

Examples:

- Binary search
- Quicksort
- Mergesort
- Fast Integer Multiplication

Recursion

BST Sum

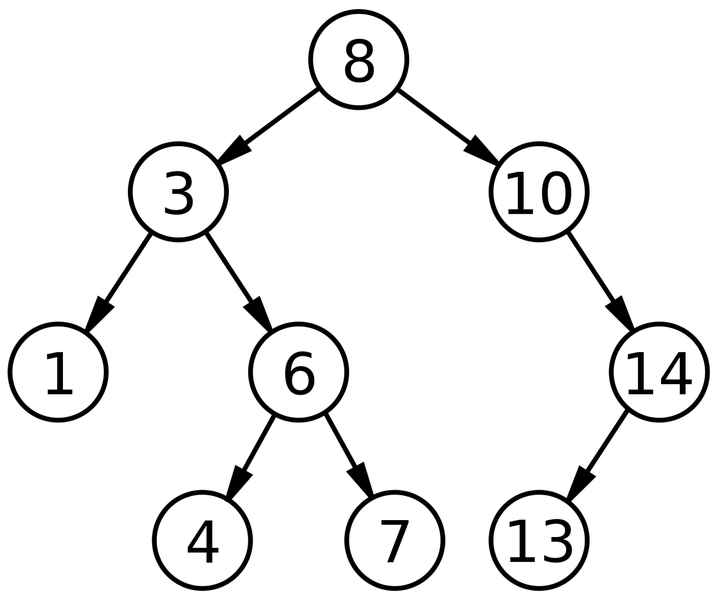
-Find the sum of a BST where each node has an integer

Linked List Merge

-Merge two sorted Linked Lists in place

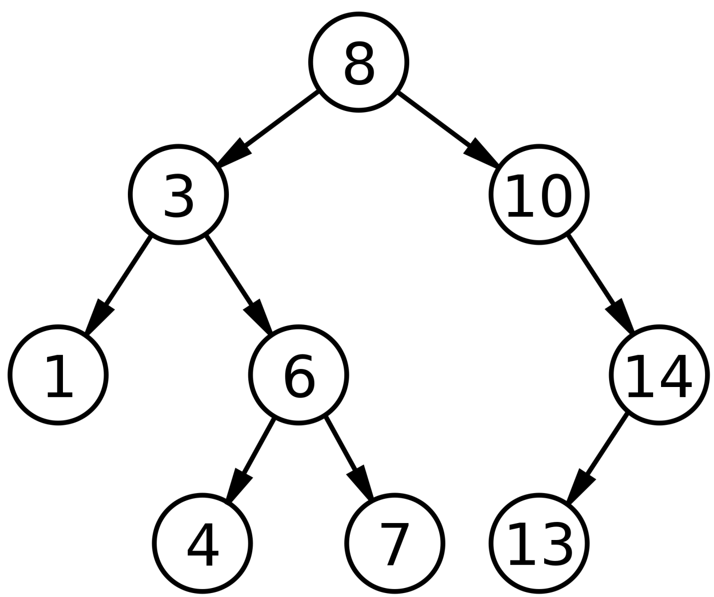
BST Sum

Problem: Find the sum of all the nodes in a BST where each node has an integer.



BST Sum

Solution: Pass the values of the each node from the leaves to the root and sum them off of the recursive stack.



BST Sum

```
int bstSum(Node n) {
   if (n == null)
         return 0;
   return n.value + bstSum(n.left) +
               bstSum(n.right);
}
```

Linked List Merge

Problem: Merge two sorted Linked Lists in place.

Linked List Merge

Problem: Merge two sorted Linked Lists in place.

Solution: Use recursion to pass back the appropriate “next” node to the previous nodes.

Linked List Merge

```
Node merge(Node list1, Node list2) {
      if (list1 == null) { return list2; }
      if (list2 == null) { return list1; }

      if (list1.val < list2.val) {
         list1.next = merge(list1.next, list2);
         return list1;
      }
      else {
         list2.next = merge(list1, list2.next);
         return list2;
      }
}
```

Study Guide

Practice a lot of recursion problems:

- -Develop base case instinct
- -Learn data passing themes
- -Analyze runtime

Trees, sorting, searching

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Greedy

Greedy algorithms take the optimal choice at each local step, which produces an optimal/almost-optimal global result.

Greedy

Coin change

-Minimum number of coins needed to represent *n* cents

Kruskal's Algorithm

-Minimum Spanning Tree

Coin Change

Problem: Find the minimum number of coins needed to represent *n* cents.

Coin Change

Problem: Find the minimum number of coins needed to represent *n* cents.

Solution: Starting from the largest denomination, use as many coins as you can until you have to move to a smaller denomination.

Coin Change

```
int coinChange(int n) {
   int numCoins = 0;

   while (n >= 25) {
         n -= 25;
         numCoins++;
   }
   while (n >= 10) {
         n -= 10;
         numCoins++;
   }
   ...
   return numCoins;
}
```

Kruskal's Algorithm

Problem: Find a Minimum Spanning Tree of a graph.

Kruskal's Algorithm

Problem: Find a Minimum Spanning Tree of a graph.

Solution: Repeatedly select the smallest edge that does not form a cycle with the selected edges.

Kruskal's Algorithm

```
function kruskal(set of edges) {
    -init a set of edges to represent the MST edges
    -init a set for each vertex (to detect cycles)
    -init a min heap and add all graph edges into it
    -while heap is not empty:
          -pop the min edge
          -if the min edge does not form a cycle with the
          MST edges:
                -add the edge to the MST edges set
                -union the vertex sets
    -return the MST edges set
}
```

Study Guide

Study common greedy problems:

- -Activity Scheduling
- -Coin Change
- -MST
- -Graph Bipartition

Build intuition on whether a greedy strategy could be applicable to a problem

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Dynamic Programming

Building up to an optimal solution to a problem using the optimal solutions to subproblems.

DP

DP

- -bottom-up
- -optimal substructure
- -overlapping, repeating subproblems
- -tabulation vs memoization

DP vs Recursion

DP

- -bottom-up
- -optimal substructure
- -overlapping, repeating subproblems
- -tabulation vs memoization

Recursion

- -top-down
- -distinct subproblems

Dynamic Programming

Rod Cutting

-Cut a rod into discrete pieces, each length has a value, maximize value

Longest Increasing Subsequence

-Find the length of the longest subsequence in an array of integers

Rod Cutting

Problem: Given a rod of length n, a table of lengths and values, and unlimited cuts, determine the maximum value obtainable.

Rod Cutting

Problem: Given a rod of length n, a table of lengths and values, and unlimited cuts, determine the maximum value obtainable.

value	1	5	8	9	10	17	18	20
length	1	2	3	4	5	6	7	8

For n = 8, the maximum value is 22 by cutting the rod into two rods of lengths 2 and 6.

Rod Cutting

Solution:

dp[i] stores the optimal value attainable from a rod of length i

Compute dp[i] by considering all indices j less than i
    find the maximum (value[j] + dp[i – j]) and set
    dp[i] to this value

The solution is in dp[n]

Rod Cutting

```
int cutRod(int[] value, int n) {
    int[] dp = new int[n + 1];

    for (int i = 1; i <= n; i++) {
            int max = Integer.MIN_VALUE;
            for (int j = 1; j < i; j++) {
                    max = Math.max(max, value[j]
                                            + dp[i - j]);
            }
            dp[i] = max;
    }
    return dp[n];
}
```

Rod Cutting

Time Complexity: $O(n^2)$
Space Complexity: $O(n)$

Classic recursive solution has a time complexity of $O(2^N)$

Longest Increasing Subsequence

Problem: Find the length of the longest increasing subsequence in an array of integers.

Longest Increasing Subsequence

Problem: Find the length of the longest increasing subsequence in an array of integers.

```
arr = [8, 2, 5, 3, 10, 1, 30, 76]
lis = [2, 5, 10, 30, 76]
```

Longest Increasing Subsequence

Solution:

dp[i] stores the length of the LIS that ends at the element at index i

Compute dp[i] by considering all indices j less than i

    if (dp[j] + 1 > dp[i]) and (arr[j] < arr[i])
        then we can update dp[i]

The solution is the maximum value in the dp array

Longest Increasing Subsequence

```
int lis(int[] arr) {
    // Initialize dp array and set all entries to 1
    int dp[] = new int[arr.length];
    for (int x = 0; x < n; x++) dp[x] = 1;

    // Fill in dp array
    for (int i = 0; i < n; i++)
        for (int j = 0; j < i; j++)
            if (arr[j] < arr[i] && dp[j] + 1 > dp[i])
                dp[i] = dp[j] + 1;

    // Find lis length
    int max = 0;
    for (x = 0; x < n; x++)
        max = Math.max(max, dp[x]);

    return max;
}
```

Longest Increasing Subsequence

Time Complexity: $O(n^2)$
Space Complexity: $O(n)$

There exist more efficient algorithms for LIS: O(nlogn) solution

Study Guide

Focus on 1D DP problems:

- -Base case (initialize array)
- -Recurrence (build the array)
- -Solution (where in the array is it?)

The hardest part is figuring out how to build the recurrence

Extra-credit: Practice some 2D DP problems

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Definitely know

Sorting

Recursion

Good-to-know

Greedy

Dynamic Programming

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Resources

Most interviews don't demand much formal algorithms knowledge.

Problems
- -HackerRank
- -GeeksForGeeks
- -Leetcode
- -CTCI

Theory
- -Analysis of Algorithms (CSOR 4231)
- -CLRS

Algorithms for Interviews

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