

CS 561, HW3

Prof. Jared Saia, University of New Mexico

Due: September 28th

1. Problem 4-5 (VLSI chip testing) - This is a really good divide and conquer problem that I left out of the last hw
2. Show via induction that a full parenthesization of an n element expression has exactly $n - 1$ pairs of parenthesis.
3. Find the optimal parenthesization for a matrix-chain product whose sequence of dimensions is: $(3, 2, 4, 1, 2)$. (Don't forget to include the table used to compute your result)

4. A bakery sells donuts in boxes of three different quantities, x_1 , x_2 , and x_3 . In the Donut Buying problem, you are given the numbers x_1 , x_2 and x_3 , and an integer n and you should return either 1) the minimum number of boxes needed to obtain exactly n donuts if this is possible, along with a set of boxes that obtains this minimum; or 2) "DOH!" if it is not possible to obtain exactly n donuts.

For example if $x_1 = 4$, $x_2 = 6$, $x_3 = 9$ and $n = 17$, then you should return that 3 boxes suffices, with 2 boxes of size 4, and 1 box of size 9. However, if $n = 11$, you should return "DOH!" since it is not possible to buy exactly 11 donuts with these box sizes.

- (a) For any positive x , let $m(x)$ be the minimum number of boxes needed to buy x donuts if this is possible, or INFINITY otherwise. Write a recurrence relation for the value of $m(x)$. Don't forget the base case(s)!
 - (b) Give an efficient algorithm for solving Donut Buying. How does its running time depend on x_1 , x_2 , x_3 , and n ? Is it an algorithm that runs in polynomial time in the input sizes?
5. A h-tree is a rooted binary tree defined as follows. For ℓ a power of 2, a tree with ℓ leaf nodes is a h-tree iff the tree is perfect (recall that a

perfect binary tree is one where all non-leaf nodes have two children, and all leaf nodes have the same depth). For ℓ not a power of 2, a tree with ℓ leaf nodes is a h-tree if and only if (1) the root node, r , has two children; (2) the left subtree of r is the root of a perfect binary tree with $2^{\lceil \log \ell \rceil}$ leaf nodes; and (3) the right subtree of r is a h-tree.

Show the following by induction:

- For all positive ℓ , there is a unique h-tree with ℓ leaf nodes.
 - Call the h-tree with ℓ leaf nodes $\text{h-tree}(\ell)$. Then, the height of $\text{h-tree}(\ell)$ is $\lceil \log \ell \rceil$
6. Problem 15-5 (2nd)/ 15-7 (3rd) (Viterbi Algorithm). Note in this problem, a label can appear on more than one edge in the graph, and can even appear on more than one edge leaving a given node in the graph.
 7. Gus wants to open franchises of his restaurant, *Los Pollos Hermanos*, along Central Avenue. There are n possible locations for franchises, where location i is at mile i on Central. Each location $i > 1$, is thus a distance of 1 mile from the previous one. There are two rules.
 - At each location, there can be at most one restaurant, and the profit of a restaurant at location i is p_i , where p_i is always positive.
 - Any two restaurants must be at least 2 miles apart.
 - (a) Jesse proposes the following algorithm: Sort the locations by decreasing p_i values, then greedily choose the next possible location, provided that it doesn't conflict with previously chosen locations. Show that Jesse's algorithm doesn't always give maximum profit.
 - (b) Now consider a dynamic programming approach to this problem. For $i \geq 0$, let $m(i)$ be the maximum profit obtainable by using locations 1 through i . Write a recurrence relation for $m(i)$. Don't forget the base case(s).
 - (c) Describe how you would create a dynamic program using the previous recurrence. What is the run time of your algorithm?
 - (d) Now Gus wants to solve a generalization of the problem. There are two changes. First, for $1 < i \leq n$, location i is now distance d_i from location $i - 1$. Second, any two restaurants must now be distance k apart for some parameter k . Write a new recurrence relation for this problem. Don't forget the base case(s).