Problem Set 5

This problem set is due at 11:59pm on Friday, March 20, 2015.

Turn in your solution to all problems in a single pdf file to Stellar. Your submitted solution should start with your name, the course number, your recitation section, the date, and the names of any students with whom you collaborated.

Exercise 5-1. Read CLRS, Chapter 11.

Exercise 5-2. Exercise 11.3-5.

Exercise 5-3. Read CLRS, Chapter 14.

Exercise 5-4. Exercise 14.3-3.

Exercise 5-5. Read CLRS, Chapter 15.


Exercise 5-7. Exercise 15.2-4.

Exercise 5-8. Exercise 15.4-5.

Problem 5-1. New Operations for Skip Lists [25 points]

This problem will demonstrate that skip lists, and some augmentations of skip lists, can answer some queries about “nearby” elements efficiently. In a dynamic-set data structure, the query \textsc{Finger-Search}(x,k) is given a node \(x\) in the data structure and a key \(k\), and it must return a node \(y\) in the data structure that contains key \(k\). (You may assume that such a node \(y\) in fact appears in the data structure.) The goal is for \textsc{Finger-Search} to run faster when nodes \(x\) and \(y\) are nearby in the data structure.

(a) [12 points] Write pseudocode for \textsc{Finger-Search}(x,k) for skip lists. Assume all keys in the skip list are distinct. Assume that the given node \(x\) is in the level-0 list, and the operation should return a node \(y\) that stores \(k\) in the level-0 list.

Your algorithm should run in \(O(\lg m)\) steps with high probability, where \(m = 1 + |\text{rank}(x.key) - \text{rank}(k)|\). Here, \(\text{rank}(k)\) refers to the rank (index) of a key \(k\) in the sorted order of the dynamic set (when the procedure is invoked). “High probability” here is with respect to \(m\); more precisely, for any positive integer \(\alpha\), your algorithm
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Problem 5-2. Choosing Prizes [25 points]

In this problem, you are presented with a collection of \( n \) prizes from which you are allowed to select at most \( m \) prizes, where \( m < n \). Each prize \( p \) has a nonnegative integer value, denoted \( p.value \). Your objective is to maximize the total value of your chosen prizes.

The problem has several variations, described in parts (a)–(d) below. In each case, you should give an efficient algorithm to solve the problem, and analyze your algorithm’s time and space requirements.

In parts (a)–(c), the prizes are presented to you as a sequence \( P = \langle p_1, p_2, \ldots, p_n \rangle \), and your algorithm must output a subsequence \( S \) of \( P \). In other words, the selected prizes \( S (|S| = m) \) must be listed in the same order as they are in \( P \).

(a) [4 points] Give an algorithm that returns a subsequence \( S = \langle s_1, s_2, \ldots \rangle \) of \( P \) of length at most \( m \), for which \( \sum_j s_j.value \) is maximum. Analyze your algorithm in terms of \( n \) and \( m \).

(b) [7 points] Now suppose there are two types of prizes, type \( A \) and type \( B \). Each prize’s type is given as an attribute \( p.type \). Give an algorithm that returns a subsequence \( S = \langle s_1, s_2, \ldots \rangle \) of \( P \) of length at most \( m \), for which \( \sum_j s_j.value \) is maximum, subject to the new constraint that, in \( S \), all the prizes of type \( A \) must precede all the prizes of type \( B \). Analyze your algorithm in terms of \( n \) and \( m \).
(c) [7 points] As in part (a), there is only one type of prize. Give an algorithm that returns a subsequence $S = \langle s_1, s_2, \ldots \rangle$ of $P$ of length at most $m$, for which $\sum_j s_j.value$ is maximum, subject to the new constraint that, in $S$, the values of the prizes must form a non-decreasing sequence. Analyze your algorithm in terms of $n$ and $m$.

In part (d), the prizes are represented by a rooted binary tree $T$, with root vertex $r$, where each vertex $u$ has an associated prize, $u.prize$. Let $P$ be the set of prizes in the tree. As before, each prize $p$ has a nonnegative integer attribute $p.value$.

(d) [7 points] Give an algorithm that returns a set $S$ of at most $m$ prizes for which $\sum_{s \in S} s.value$ is maximum, subject to the new constraint that, for any $s \in S$ that is associated with a non-root node $u$ of $T$, the prize at node $u.parent$ is also in $S$. (This implies that the selected prizes must be associated with nodes that form a connected subtree of $T$ rooted at $r$.)