CS180 Exam 1

TOTAL POINTS

20.5 / 22

QUESTION 1

Problem 1 8 pts

1.1 Asymptotic notation **1 / 1**

✓ **- 0 pts** **6 out of 6**

- 0.25 pts 5 out of 6

- 0.4 pts 4 out of 6

- 0.5 pts 3 out of 6

- 0.6 pts 2 out of 6

- 0.75 pts 1 out of 6

- 0.75 pts 0 out of 6

1.2 True or False: DC **1 / 1**

✓ **- 0 pts** **Correct**

- 0.4 pts Wrong answer but correct formula formed

- 0.5 pts Wrong answer with wrong formula

- 0 pts Correct but wrong explanation

1.3 Principles of DC **1 / 1**

✓ **- 0 pts** **Correct**

- 0.4 pts divide not mentioned

- 0.4 pts merge not mentioned

1.4 Solving recurrence **1 / 1**

✓ **- 0 pts** **used master theorem**

- 0 pts Used expansion

- 0.5 pts wrote the master theorem components but wrong reasoning

- 0.75 pts master theorem components are wrong

- 0.5 pts used expansion but wrong answer

- 0.75 pts wrong attempt for expansion

1.5 Karatsuba trick **1 / 1**

✓ **- 0 pts** **Correct**

- 0.5 pts wrong formation of trick

- 0.75 pts no usage of trick at all

1.6 List vs Matrix representations **1 / 1**

✓ **- 0 pts** **Correct**

- 0.5 pts no mention of space

- 0.5 pts no mention of edge access time

- 0.75 pts missing considerations of space and edge access times

1.7 Definition of path **1 / 1**

✓ **- 0 pts** **Correct**

- 0.5 pts Incorrect definition / not generic

1.8 Checking if graph is connected **1 / 1**

✓ **- 0 pts** **Correct**

- 0.7 pts Wrong Answer

- 0.5 pts Did not check if all vertices are discovered

- 0.5 pts Did not check if all vertices are connected/discovered. Just checked one.

QUESTION 2

2 Sorting sorted arrays **4 / 4**

✓ **- 0 pts** **Correct**

- 1.5 pts using mergesort to combine 2 sorted arrays. Gives runtime O((nk) log(nk)) - more than allowed.

- 1 pts unclear merge step

- 1.5 pts heap ops should be stated and clarified as these were not covered in class.

- 1.75 pts reasonable attempt but missing crucial details and/or not correct.

- 2.25 pts Missing crucial details and/or not correct.

- 3 pts attempt something relevent

- 3.5 pts attempt something irrelevent

- 4 pts empty

- 3 pts Solution runs in time O(n k^2) time, much more than the O(nk log k) the problem was looking for.

QUESTION 3

3 Finding plurality elements **4 / 4**

✓ **- 0 pts** **Correct**

- **0.5 pts** no base case
- **1.5 pts** no/wrong run-time analysis or no recurrence relation of the time complexity
- **1.5 pts** no/wrong counting of returned elements from the recursion in the merge part
- **1.75 pts** reasonable attempt but not returning all plurality elements
- **2.25 pts** reasonable attempt with an algorithm running in time O(n^2) or worse.
- **2.5 pts** attempt missing many details and not correct.
- **3.25 pts** not a reasonable attempt
- **4 pts** no answer

QUESTION 4

4 Closest pair L4-distance **2.5 / 4**

- **0 pts** Correct
- **0 pts** You check way too many points for S_y and didn't show how you derived the number. Try to simplify your strip construction./ Or show how you derive this number
- **2.25 pts** reasonable attempt but missing many crucial details and/or not correct.
- **2.5 pts** moderate attempt but missing many crucial details and/or not correct.
- **1.5 pts** Didn't state how to compute/how to organize the points in the strip S. (for example, "sort by y coordinate" or including which points in strip or the width/height of grid) or Wrong way to construct the strip and grid.
- **1.5 pts** Didn't mention how many points to look up for each S_y in the strip
- **1.5 pts** Didn't Identify the divide-conquer high-level steps correctly
- **4 pts** No answer

✓ - **1.5 pts** **wrong number of points to look up**

QUESTION 5

5 BFS trace **2 / 2**

✓ - **0 pts** **Correct**

- **1 pts** Extra lists than needed (You have mostly not considered the edges {4,6} {5,6} in line 2 of the Question)
- **1 pts** Extra lists than needed
- **1 pts** L[2] has extra elements
- **0.75 pts** L[2] order of elements wrong
- **0.5 pts** L[1] order of elements wrong

Exam 1. April 25, 2018

CS180: Algorithms and Complexity
Spring 2018

Guidelines:

- The exam is closed book and closed notes. Do not open the exam until instructed to do so.
- Write your solutions clearly and when asked to do so, provide complete proofs. You may use results and algorithms from class without proofs or details **except for Problem 4** as long as you state what you are using.
- I recommend taking a quick look at all the questions first and then deciding what order to tackle to them in. Even if you don't solve the problems fully, attempts that show some understanding of the questions and relevant topics will get reasonable partial credit.
- You can use extra sheets for scratch work, but you can only use the white space (it should be more than enough) on the exam sheets for your final solutions.
- Most importantly, make sure you adhere to the policies for academic honesty set out on the course webpage. The policies will be enforced strictly and any cheating reported with the score automatically becoming zero.
- Write clearly and legibly. All the best!

Problem	Points	Maximum
1		8
2		4
3		4
4		4
5		2
Total		22

Name	
UID	
Section	

$$\frac{\log_b a}{\log_b c} = \log_c a.$$

1 Problem

The answers to the following should fit in the white space below the question.

1. For each pair (f, g) below indicate the relation between them in terms of O, Ω, Θ. For each missing entry, write-down Y (for YES) or N (for NO) to indicate whether the relation holds (no need to justify your answers here). For example, if $f = O(g)$ but not $\Omega(g)$, then you should enter Y in the first box and N in the other two boxes. Similarly, if $f = \Theta(g)$, then you should enter Y in all the boxes. [1 point]

f	g	O	Ω	Θ
n^2	$n^2 - 2n + 2$	Y	Y	Y
$\log_2 n$	$(\log_{100} n)^2$	Y	N	N

$O(\log n)$ $O((\log n)^2)$

$\log_2 9$

$\log_2 n = \log_{100} n \log_2 100$

$n = O(n^2)$

$n^2 = \Omega(n)$

2. Is the following True or False: Consider a divide and conquer algorithm which solves a problem on an instance of length n by making six recursive calls to instances of length $\lfloor n/3 \rfloor$ each, and combines the answers in $O(n^2)$ time. Then, the time-complexity of the algorithm is $O(n^2)$. [1 point]

$T(n) = 6T(\frac{n}{3}) + O(n^2)$

$n^{\log_3 6} < n^2$

$\boxed{\text{TRUE}}$

3. State the principles behind the divide and conquer technique for designing algorithms. [1 point]

- Divide the problem into subproblems that are simpler to solve
- Recursively solve the subproblems
- Use the answers from the subproblems to solve the original (higher level) problem.

4. What is the solution to the recurrence $T(1) = 1$, $T(n) = 2T(n/2) + 10n$? [1 point]

~~f(n)~~ $n^{\log_2 2} = n$

$\boxed{T(n) = O(n \log n)}$

5. Let a_0, a_1, b_0, b_1 be four integers that are k bits long. Write down Karatsuba's trick (that we used in class for fast integer multiplication) to compute the four products $a_1 \cdot b_1, a_1 \cdot b_0, a_0 \cdot b_1, a_0 \cdot b_0$ using only three multiplications and some additions and subtractions.

executed		result
let $c = a_1 \cdot b_1$	=	$a_1 \cdot b_1$
let $d = a_0 \cdot b_0$	=	$a_0 \cdot b_0$
$(a_1 + a_0)\cdot(b_1 + b_0) - c - d$	=	$a_1 \cdot b_0 + a_0 \cdot b_1$

3 multiplications, 2 additions, 2 subtractions

6. Write down some pros and cons of the adjacency-list and adjacency-matrix representations of graphs. [1 point]

	Adjacency-List	Adjacency-Matrix
Pros:	More efficient size of representation: $O(\lvert V\rvert + \lvert E\rvert)$	More efficient lookup time to check for vertices being adjacent: $O(1)$
Cons:	Longer lookup time to find if vertices a and b are adjacent: $\Omega(\lvert V\rvert)$	Inefficient size of the representation: $O(\lvert V\rvert^2)$

7. Write down the definition of a path in a graph $G = (V, E)$. [1 point]

A path is the set of vertices $\in V$ and edges $\in E$ that make two vertices connected. The starting vertex and ending vertex will have one edge connecting each of them to one neighbor. Any other vertices in the path will have 2 edges and 2 neighboring vertices. There are no cycles. Every vertex in the path is connected to every other vertex in the path.

8. How can we efficiently check if a graph given in adjacency-list representation is connected? (You can refer to algorithms done in class without writing them out fully.) [1 point]

You can run BFS starting at the first vertex in the adjacency-list. If not all vertices are flagged as "discovered" in the DISCOVERED array then the graph is not connected. If every vertex is flagged as discovered it is connected.

2 Problem

You are given k sorted arrays, each with n numbers in them. Give an algorithm for merging these arrays into a single sorted array of numbers that runs in time $O(nk \log k)$. You don't have to analyze the running time or prove correctness. [4 points]

(You can assume that the solution to the following recurrence is $O(nk \log k)$: $T(1) = O(1)$, $T(k) \leq 2T(k/2) + O(n \cdot k)$.)

List of arrays

```
Merge-Sorted-Arrays (k, n ; LA)
    make an array R size k·n
    IF k=1: return LA[0]
    IF k=2:
        let i=0, j=0, m=0
        while (m ≠ k·n) {                    // constant
            if LA[0][i] < LA[1][j]:
                R[m] = LA[0][i]
                i++
            else:
                R[m] = LA[1][j]
                j++
            m++
        }
        return R

    Divide LA into LA0 and LA1, both size k/2
    R0 = Merge-Sorted-Arrays (k/2, n, LA0)      // 2T(k/2)
    R1 = Merge-Sorted-Arrays (k/2, n, LA1)
    let i=0, j=0, m=0
    while (m≠k·n) {
        if R0[i] < R1[j]:
            R[m] = R0[i]                          // O(n·k)
            i++
        else:
            R[m] = R1[j]
            j++
        m++
    }
    return R
```


$T(n) = 2T(\frac{k}{2}) + O(nk)$

3 Problem

Given an array $A[0, 1, \ldots, n-1]$, an element $A[i]$ is said to be a *pluraility element* if more than $\lfloor n/3 \rfloor$ of its elements equal elements of A. For example, the array $A = [1, 11, 2, 4, 2, 2, 1, 2, 4]$ has one plurality element 2; the array $A = [1, 1, 2, 4, 2, 2, 1, 2, 1]$ has two plurality elements 1, 2; the array $A = [1, 11, 2, 1, 2, 1, 11, 2, 11]$ has no plurality elements.

Given an array as input, the task is to design an efficient algorithm to tell whether the array has any plurality elements and, if so, to find **all** the plurality elements. The elements of the array are not necessarily from some ordered domain like the integers, and so there can be no comparisons of the form "is $A[i] > A[j]$?". (Think of the array elements as mp3 files, say; so in particular, you cannot sort the elements.) However you can answer questions of the form: "is $A[i] = A[j]$" in constant time.

Give an algorithm to solve the problem. For full-credit, your algorithm should be correct and run in time $O(n \log n)$ and you should bound the run-time of the algorithm. (You don't have to prove correctness.). [4 points]

defining return type

(P, m) = Find-Plurality (A, n)

set of plurality elements · # of elements, at most 3

m = 0, P = empty

If n = 1: P = A; m = n; return (P, m)

If n = 2: P = A; m++

If A[1] ≠ A[0]: m++ // constant

return (P, m)

If n = 3: P[0] = A[0]; m++

If A[1] ≠ A[0] : P[1] = A[1]; m++

If A[2] ≠ A[0] and A[2] ≠ A[1]: P[m+1] = A[2]; m++

return (P, m)

Let A_0 = first half of A, A_1 = second half of A

P_0, m_0 = Find-Plurality (A_0, $n/2$) // $2T(\frac{n}{2})$

P_1, m_1 = Find-Plurality (A_1, $n/2$)

Put shared elements of P_0 and P_1 into P // O(1)

m = # of elements in P

For elements not shared between P_0 and P_1: // at most 6, so this doesn't contribute to O(1)

Iterate through A, counting instances of that element // O(n)

if count ≥ n/3:

put element in P; m++

Return (P, m)

$$\boxed{\begin{aligned} T(n) &= 2T(\tfrac{n}{2}) + O(n) \\ &= O(n \log n) \end{aligned}}$$

also $\Omega(n)$

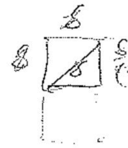
looking w/ 4 boxes should be safe

δ

$\delta\sqrt{2}$

$\delta^4 = |x-x'|^4 + |y-y'|^4$

$C = 2^{1/4}$



$\left(\frac{\delta^4}{C^4} + \frac{\delta^4}{C^4}\right)^{1/4} = \delta = \frac{2^{1/4}\delta}{C}$

4 Problem

Given a set of points $P = \{p_1, \ldots, p_n\}$ in the plane, give an algorithm for finding a pair of points with the smallest possible L4-distance among the points where L4-distance between two points is defined by $d_4((x,y),(x',y')) = (|x-x'|^4 + |y-y'|^4)^{1/4}$.

For full-credit your algorithm should be correct and run in time $O(n \log n)$. You don't have to prove correctness or analyze the run-time of the algorithm. You should describe all the steps in the algorithm at a level of detail similar to what was done in class (however, you don't have to describe how to manipulate the sorted lists). [4 points]

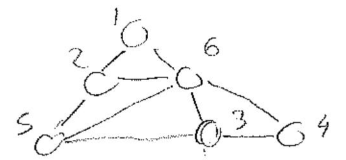
```
Smallest-L4-Distance(P, n)
|  Px = sorted P by x-coordinate      // merge sort
|  Py = sorted P by y-coordinate      // merge-sort
|  Smallest-L4-Dist-Work(Px, Py)

Smallest-L4-Dist-Work(Px, Py)
|  If size of Px ≤ 3:
|  |  compute d4 distance between all points
|  |  return pair w/ shortest distance
|  Let Qx = first half of Px
|  Let Qy = Qx ordered by y-coordinate, found from Py
|  Let Rx = last half of Px
|  Let Ry = Ry ordered by y-coordinate, found from Py
|  (q0,q1) = Smallest-L4-Dist-Work(Qx, Qy)
|  (r0,r1) = Smallest-L4-Dist-Work(Rx, Ry)
|  δ = min(d4((q0),(q1)), d4((r0),(r1)))
|  Let Sx = set of points within ±δ on the x-axis from the last element in Qx
|  find Sy from Sx using Py
|  δ1 = δ+1, (p0, p1) = null
|  For every s ∈ Sy:
|  |  for every 3 u in front of s:
|  |  |  compute d4 distance between points
|  |  |  if a distance is < δ1: δ1 = that distance; (p0,p1) = that set of points
|  if δ1 < δ
|  |  return (p0, p1)
|  else if d4((q0),(q1)) == δ:
|  |  return (q0, q1)
|  else:
|  |  return (r0, r1)
```

5 Problem

Let $G = (V, E)$, where $V = \{1, 2, 3, 4, 5, 6\}$ and $E = \{\{1, 2\}, \{1, 6\}, \{2, 5\}, \{2, 6\}, \{3, 4\}, \{3, 5\}, \{3, 6\}, \{4, 6\}, \{5, 6\}\}$. Suppose that G was given to you in adjacency list representation where the elements in the adjacency list are ordered in increasing order. For example, the adjacency list of vertex 2 would be $[1, 5, 6]$. Run the BFS algorithm on G starting from the vertex 1. It suffices to show the step-by-step evolution of the lists $L[0], L[1], \ldots$ as we described in class. [2 points]

A
1
2
3
4
5
6



L	DISCOVERED 1	2	3	4	5	6
$L[0] = \{1\}$	T	F	F	F	F	F
$L[1] = \{2, 6\}$	T	T	F	F	F	T
$L[2] = \{5, 3, 4\}$	T	T	T	T	T	T