Computer Science Foundation Exam

May 22, 2021

Section I A

DATA STRUCTURES

ONLINE EXAM

Directions: You may either directly edit this document, or write out your answers in a .txt file, or scan your answers to .pdf and submit them in the COT 3960 Webcourses for the Assignment "Section I A". Please put your _name, UCFID and NID_ on the top left hand corner of each document you submit. Please aim to submit 1 document, but if it's necessary, you may submit 2. Clearly mark for which question your work is associated with. If you choose to edit this document, please remove this cover page from the file you submit and make sure your _name, UCFID and NID_ are on the top left hand corner of the next page (first page of your submission).

Question #	Max Pts	Category	Score
1	10	DSN	
2	10	DSN	
3	5	ALG	
TOTAL	25		

You must do all 3 problems in this section of the exam.

Problems will be graded based on the completeness of the solution steps and <u>not</u> graded based on the answer alone. Credit cannot be given unless all work is shown and is readable. Be complete, yet concise, and above all <u>be neat</u>. For each coding question, assume that all of the necessary includes (stdlib, stdio, math, string) for that particular question have been made.

Name: _____
UCFID: _____
NID: _____

1) (10 pts) DSN (Dynamic Memory Management in C)

Suppose we have a stack implemented with an array as shown in the structure below. Write a function called grow_stack that will increase the stack's capacity while preserving the exact values currently in the stack and their current locations. Your function should take 2 parameters: a pointer to the current stack and an integer representing the amount to increase the stack's capacity by. **You may not use the realloc function.** You may assume s isn't NULL and pts to a valid struct stack. You may assume that capacity stores the current size of the array that the pointer array is pointing to and that top represents the number of items currently in the stack (items are stored in indexes 0 through top-1).

```
struct Stack {
      int *array;
      int top;
      int capacity;
};

void grow_stack(struct Stack *s, int increase) {
```

```
}
```

2) (10 pts) DSN (Linked Lists)

Suppose we have a singly linked list implemented with the structure below. Write a function that will convert it into a circular linked list and return the pointer to the beginning of the circle.

```
struct node {
    int num;
    struct node* next;
};

struct node* make_circle(struct node* head) {
```



```
}
```

3) (5 pts) ALG (Stacks)

Convert the following infix expression to postfix using a stack. Show the contents of the stack at the indicated points (1, 2, and 3) in the infix expression.

$$\overset{1}{} \qquad \overset{2}{} \qquad \overset{3}{}$$

$$\textbf{A} + \textbf{(B} * \textbf{(C} - \textbf{D} \qquad \textbf{))} + \textbf{((E} / \qquad \textbf{F)} + \textbf{G)} \qquad + \textbf{H}$$

1

2

3

Resulting postfix expression:

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Section I B

DATA STRUCTURES

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1	5	ALG	
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Name: _____
UCFID: _____
NID: _____

1) (5 pts) ALG (Binary Trees)

Draw a single **binary search tree** that meets all the following conditions:

- The tree contains 7 nodes.
- The tree's pre-order traversal is the same as its in-order traversal.
- The tree does not contain any duplicate values.

If it is not possible to draw such a tree, say so and explain why not.

2) (10 pts) ALG (Hash Tables)

Consider the following strings and their corresponding hash values, which have been generated by some hash function:

hash("squiggle") = 301

hash("giggle") = 174

hash("haggle") = 431

hash("gaggle") = 263

hash("straggle") = 361

a) (7 pts) Insert the strings above into the following hash table using **quadratic probing**. In doing so, insert them in the order given above (i.e., starting with "squiggle", then "giggle", and so on). Note that the hash table's length is **11** (not 10).

		haggle		squiggle			straggle		giggle	gaggle
0	1	2	3	4	5	6	7	8	9	10

b) (3 pts) What is one hash value, *h*, between 100 and 500 (inclusively) that would cause a collision to occur in your final table from part (a) of this problem, but which also satisfies all of the following additional restrictions:

h % *table_length* != hash("squiggle") % *table_length*

h % *table_length* != hash("giggle") % *table_length*

h % *table_length* != hash("haggle") % *table_length*

h % *table_length* != hash("gaggle") % *table_length*

h % *table_length* != hash("straggle") % *table_length*

3) (10 pts) ALG (AVL Trees)

This question deals with the AVL Tree shown below:

```
            30
          /      \
       15          70
      /   \       /   \
     8    20    45     100
    /          /  \       \
   6         33   62      107
                   /
                  57
```
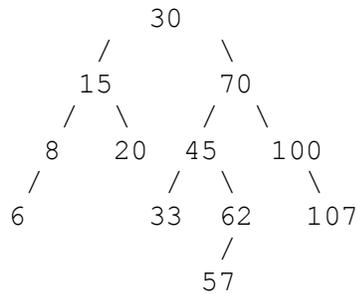
(a) (7 pts) How many restructure operations (a single restructure operation is either a single or double rotation) would occur if each of the following items was deleted? Consider each item separately as being the only item being deleted from the tree shown above. (Note: It's possible that the answer to some parts is 0.)

Item to Delete	Number of Restructure Operations
6	
20	
33	
57	
62	
100	
107	

(b) (3 pts) What is the fewest number of consecutive insertion operations that would need to occur to force a rebalance at the root node of the given tree in the picture? (Hint: In order for this to occur, there has to be the requisite height imbalance at the root node 30, and no other imbalances on the path from the last inserted node to the root.)

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Section II A

ALGORITHMS AND ANALYSIS TOOLS

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2	10	ANL	
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Name: _____
UCFID: _____
NID: _____

1) (5 pts) ANL (Algorithm Analysis)

Given an array, `vals`, of size n, one can determine the sum of the elements in the array from index i through index j (i ≤ j), inclusive, simply by running a for loop through the elements:

```
int sum = 0;
for (int z=i; z<=j; z++)
    sum += vals[z];
```

This type of sum is known as a contiguous subsequence sum.

Note: There are more efficient ways to do this if many sums of this format need to be determined, but for the purposes of this problem, assume that this is how such a sum is determined.

(a) (3 pts) What is the worst case run time of answering **q** questions about contiguous subsequence sums on an array of size **n**? Express your answer in Big-Oh notation, in terms of both **n** and **q**. Give a brief justification for your answer.

(b) (2 pts) What is the best case run time of answering **q** questions about contiguous subsequence sums on an array of size **n**? Express your answer in Big-Oh notation, in terms of both **n** and **q**. Give a brief justification for your answer.

2) (10 pts) ANL (Algorithm Analysis)

Querying a user in our data base of 10^4 users take 10 milliseconds. The runtime of the query is logarithmic with respect to the number of users. Namely, if there are n users, a query takes $O(\lg n)$ time. How many users can we support while taking no more than 20 milliseconds per query?

3) (10 pts) ANL (Summations)

What is the closed form of the following summation? Your solution should be a function in terms of n. For full credit work must be shown.

$$\sum_{i=0}^{n} \sum_{j=0}^{i} 2^j$$

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Section II B

ALGORITHMS AND ANALYSIS TOOLS

ONLINE EXAM

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Name: _____, UCFID: _____, NID: _____

1) (10 pts) DSN (Recursive Coding)

We call a list of positive integers **nice** if each pair of consecutive elements shares a common divisor greater than 1. For example, the list 18, 15, 35, 40 is nice because 18 and 15 are both divisible by 3, 15 and 35 are both divisible by 5, and 35 and 40 are both divisible by 5 as well. Given a list of unique positive integers, complete the recursive code below so that it counts the number of permutations of an original list that are nice lists. (For example, for the 4 numbers above, there are 12 nice arrangements: [18,15,35,40], [18,15,40,35], [18,40,15,35], [18,40,35,15], [15,18,40,35], [15,35,40,18], [35,15,18,40], [35,15,40,18], [35,40,18,15], [35,40,15,18], [40,18,15,35], and [40,35,15,18].)

The strategy the code below uses is to go through each permutation of the integers 0, 1, 2, …, n-1, where n is the number of values being considered. For each permutation, the evaluation function returns 1 if the order of the values creates a nice list, and 0 otherwise. Over all permutations, these values are added. Note: the gcd function provided returns the greatest common divisor shared by the 2 positive integer parameters.

```
int numArr(int values[], int perm[], int used[], int k, int n) {

    if (k == n)

        _____ ;

    int res = 0;
    for (int i=0; i<n; i++) {

        if (_____) {

            used[i] = ____;

            perm[k] = i;
            res += numArr(values, perm, used, _____ , _____ );

            used[i] = ____;
        }
    }
    return res;
}

// Returns 1 if and only if values[perm[0]], values[perm[1]], …, values[perm[n-1]]
// is a nice list. Returns 0 otherwise.
int eval(int values[], int perm[], int n) {

    for (int i=0; i< _____ ; i++)

        if ( gcd( _____ , _____ ) == ____ )
            return 0;
    return 1;
}

int gcd(int a, int b) {
    return b == 0 ? a : gcd(b, a%b);
}
```

2) (10 pts) ALG (Sorting)

(a) (5 pts) Show the state of the following array below after each iteration of an Insertion Sort. The results after the first iteration and last iteration are included for clarity.

Original	13	6	9	44	18	22	3	11
1st iteration	6	13	9	44	18	22	3	11
2nd iteration								
3rd iteration								
4th iteration								
5th iteration								
6th iteration								
7th iteration	3	6	9	11	13	18	22	44

(b) (5 pts) List the **<u>worst case</u>** run time of each of the following sorting algorithms, in terms of n, the number of items being sorted.

      (i) Insertion Sort   _____

      (ii) Selection Sort   _____

      (iii) Heap Sort   _____

      (iv) Merge Sort   _____

      (v) Quick Sort   _____

3) (5 pts) ALG (Bitwise Operators)

There are a total of 25 cards, numbered 0 through 24. We can represent a set of cards with a single integer by setting the ith bit to 1 if the set contains card i, and setting the bit to 0 otherwise. For example, the set of cards {2, 6, 7} would be stored as the integer 196, since $196 = 2^7 + 2^6 + 2^2$. Two sets of cards are disjoint, if and only if no card appears in both sets. Complete the function below so that it returns 1 if the sets of cards represented by the integers set1 and set2 are disjoint, and returns 0 if they are not disjoint. (For example, disjoint(196, 49) should return 1 because $49 = 2^5 + 2^4 + 2^0$, and there is no common value in the two sets {2, 6, 7} and {0, 4, 5}. On the other hand, disjoint(196, 30) should return 0 because $30 = 2^4 + 2^3 + 2^2 + 2^1$, so that card number 2 is included in both sets 196 and set 30.)

```
// Pre-condition: set1 and set2 are bitmasks in between 0 and
//                (1<<25)-1.
// Post-condition: Returns 1 if the two bitmasks are disjoint,
//                 meaning that the sets they represent don't have
//                 any items in common, and returns 0 otherwise, if
//                 the two represented sets do have common items.
int disjoint(int set1, int set2) {




}
```