Santa Monica College
Fall 2018

CS 20A: Data Structures with C++

Quiz 2

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Problem 1: Partition a Doubly Linked List

Consider the quicksort partition implementation for arrays in the lecture slides. Translate that partition function to operate on a doubly linked list. It takes pointers to the first and last nodes in the list and will return a pointer to the pivot node. There are several different ways of implementing such a partition function, but I want you maintain as much of the form of the original code as possible. Node definition on the right.

```
class Node {
public:
    int  value;
    Node* next;
    Node* prev;
};
```

You may assume that partition will always be given a list with at least 2 Nodes. You can also assume that you have a function called swap that correctly swaps two integers. Recall that nodes in a linked list are at random addresses, so comparisons such as less-than or greater-than do not make sense in the context of linked lists.

```
Node* partition(Node *low, Node *high) {
    Node* pNode = low;
    int pivot = low->value;
    bool lowBeforeHigh = true;
    do {
        while ( low != high && low->value <= pivot) {
            low = low->next;
        }
        if ( low == high && low->value <= pivot) {
            low = low->next;
            lowBeforeHigh = false;
        }
        while ( high->value > pivot) {
            if ( low == high) {
                lowBeforeHigh = false;
            }
            high = high->prev;
        }
        if (lowBeforeHigh) {
            swap ( low->value, high->value);
        }
    } while (lowBeforeHigh);
    swap ( pNode->value, high->value);
    pNode = high;
    return pNode;
}
```

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Problem 2: Recursion

a. Recall that we saw a version of a recursive power function in assignment 4. However, its implementation is not intuitive. Write a recursive function that computes base^{exp} (base raised to the power of exp) that is easier to understand. You may assume that exp is nonnegative. What is the Big-O of this function?

```
// Precondition: exp >= 0
int recursivePow(int base, int exp) {
    if ( exp == 0 ) {
        return 1;
    }
    return base * recursivePow (base, exp - 1);

    The Big-O is O(exp)
}
```

b. Write a function **powerThree** that, given a non-negative number **n**, returns 3^n (3^n, or "3 raised to power n") recursively, assuming 3^n is something that can be represented as an integer. Do not use a loop, and do not use the character `'*'(multiply)` anywhere in your code. What is the Big-O of this function?

```
// Precondition: n >= 0
int powerThree(int n) {
    if (n == 0) {
        return 1;
    }
    int x = powerThree (n - 1);
    return x + x + x ;

    The Big-O is O(n)
}
```

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Problem 3: Big-O

a. Suppose Algorithm A and B perform the same task. For any given input size n, algorithm A executes in $f(n)=0.003n^2$ operations, and algorithm B executes $f(n)=250n$ operations. Specifically, when does Algorithm A perform better than B?

$$0.003n^2 = 250n$$

$$\frac{0.003n^2}{0.003n} = \frac{250n}{0.003n}$$

$$n = 83,333.\overline{3}$$

↓

Alg. A and Alg. B perform the same at intersection point

$\boxed{\therefore \text{ Alg. A performs better than Alg. B when } n < 83,333.\overline{3}}$

b. An algorithm that is $O(n^2)$ takes 10 seconds to complete when n=100. How long would you expect it to take when n=500?

$(100)^2 = 10,000$ // 10s, so n = 100 is in ms

$(500)^2 = 250,000\text{ms}$ // 250s

$\boxed{\text{We would expect it to take 250 seconds when } n = 500}$

c. What is the Big-O of the following code segment:

```
for (int i = 0; i < n; i++)
    for (int j = 0; j < 4 * i; j++)
        sum++;
```

n (fixed)

$i_{max} = n-1$, rounded up to n → 4n

$n \cdot 4n$

$4n^2$

$\boxed{O(n^2)}$

d. What is the Big-O of the following function?

```
int gobidygoop(int n, int p) {
    int ac = 1;
    for (int i = 0; i < n; i++) {
        int k = p;
        while (k > 1) {
            ac *= i + k;
            k /= 4;
        }
    }
}
```

n (fixed)

$\log_4 p$ (fixed)

$n \cdot \log_4 p$

$\boxed{O(n \cdot \log_4 p)}$

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e. Consider the following pseudo code:

```
Get value for n
Set the value of k to 1
While k is less than or equal to n        n (fixed)
    Set the value of j to twice of k
    While j is greater or equal to 1      k_MAX = n → log_2 2n
        Print the value of j
        Set the value of j to one half its former value;
    Increase k by 1
```

// Assume n, k, j have type int so integer division is used

n: 4

k: 5

j: 0

What is the Big-O of this pseudocode? What does this print if n is 4?

$n \cdot \log_2 2n$

$\boxed{O(n \log_2 n)}$

Output:

2 1 4 2 1 6 3 1 8 4 2 1

Problem 5: Sorting

a. Fill out the following table or sorting properties, if there is no special condition for a particular case then leave it blank:

Sorting Algorithm	Selection	Insertion	Bubble	Quick	Merge
Average Complexity	$O(n^2)$	$O(n^2)$	$O(n^2)$	$O(n \log n)$	$O(n \log n)$
Worse Complexity	$O(n^2)$	$O(n^2)$	$O(n^2)$	$O(n^2)$	$O(n \log n)$
Condition for Worse				input already or mostly sorted OR in reverse order	
Best Complexity	$O(n^2)$	$O(n)$	$O(n)$	$O(n \log n)$	$O(n \log n)$
Condition for Best		input already or mostly sorted	input already or mostly sorted		
Stable	No	Yes	Yes	No	Yes
Can it be applied to a linked list?	Yes	Yes	Yes	Yes	Yes

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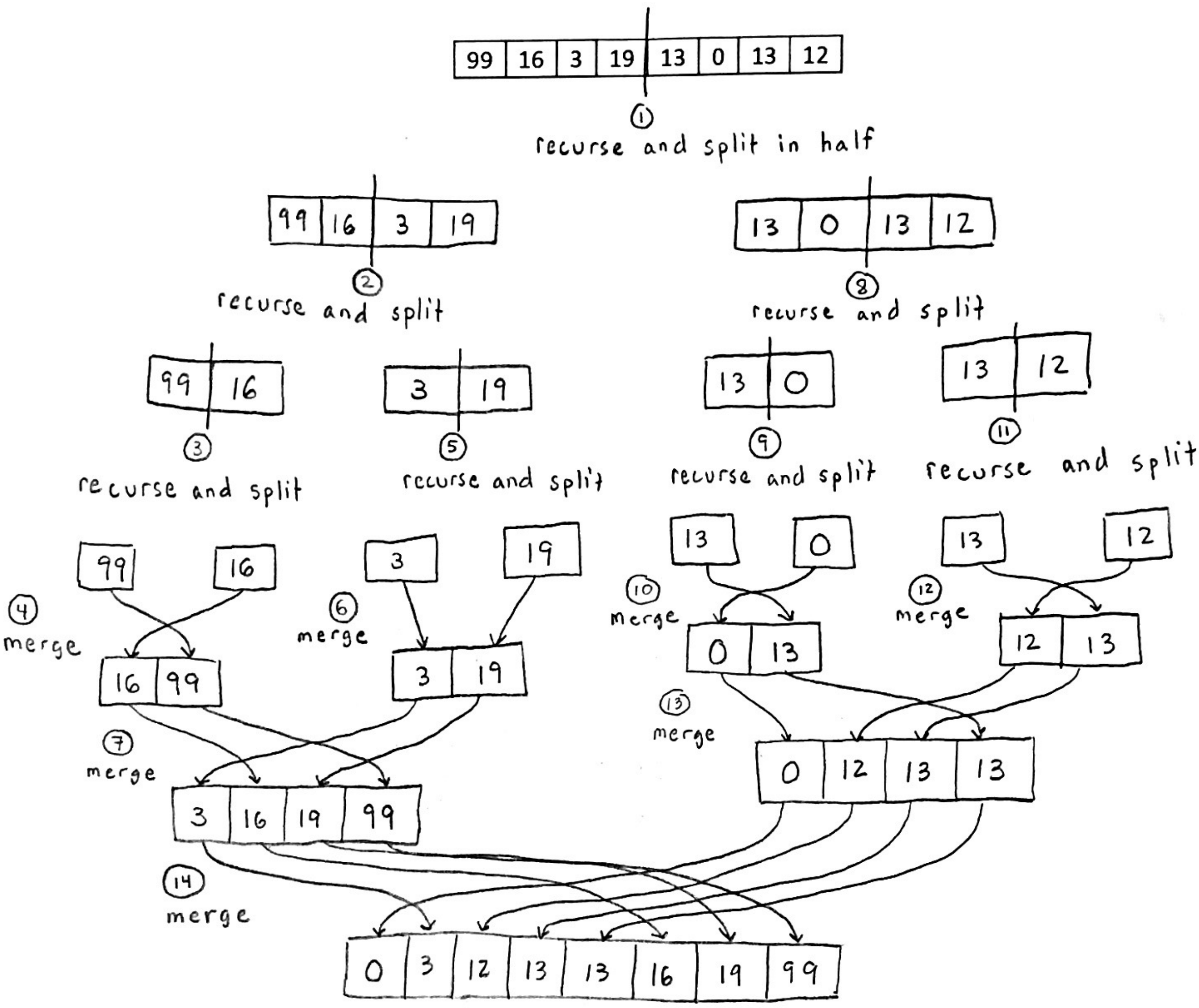
b. Sort the following array using the Mergesort algorithm. Show each recursive step, including the merge.



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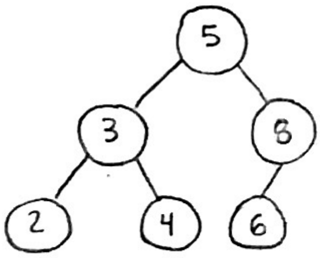
Problem 6: Tree Traversal

① ✓ ② ✓

a. Suppose we define an empty tree to have height 0. Draw a complete binary search tree with height 3 whose in-order traversal is 2,3,4,5,6,8. ③ ✓



b. What is the post-order traversal of this tree?

2, 4, 3, 6, 8, 5

c. What is the pre-order traversal of this tree?

5, 3, 2, 4, 8, 6