Indiana University Bloomington

Spring-2023
CSCI-B505 / INFO-I500
APPLIED ALGORITHMS
Examination – III

March 30, 2023, Thursday, 9:45 a.m. – 10:45 a.m.

Name & Surname	
Signature	

Rules:

1. There are 25 questions in this examination.
2. Duration of the exam is 60 minutes.
3. Write your name and surname on every page at the designated positions.
4. Put your ID card on your desk so that the proctors can check your identities.
5. The use of lecture notes, books and any other resources, calculators, computers, mobile phones, and any digital equipment is prohibited.
6. Every student taking this examination is subject to the university discipline code. Any act or attempt of cheating, including helping others, will be considered a violation of the code.

Name Surname:

1. What is the output of the algorithm **after the second pass**, while sorting the list of integers **329**, **457**, **839**, **436**, **720**, **355**, **657** in increasing order using Radix sort algorithm?

   (a) 329, 355, 436, 457, 657, 720, 839

   (b) 355, 329, 457, 436, 720, 657, 839

   (c) 720, 329, 436, 839, 355, 457, 657 ✓

   (d) 720, 355, 436, 457, 657, 329, 839

2. What does the **stable sorting** refer to ?

   (a) Time complexity remains same irrespective of whether the input is sorted or not

   (b) Time complexity increases remains constant upto a certain input size and beyond that input size the time complexiy goes exponential

   (c) The order of the equal-valued elements on the input is maintained after the sorting. ✓

   (d) It is proven in theoretical computer science that upper bound for some algorithms does not exist. These algorithms are called stable algorithms

3. Which of the following sorting algorithms has the **lowest** worst-case complexity ?

   (a) Merge sort ✓

   (b) Bubble sort

   (c) Quick sort

   (d) Selection sort

4. Consider the following statements:

   (i) Greedy choice always produces the correct answer.

   (ii) Interval Scheduling problem admits a greedy solution.

   (a) Only (i) is True

   (b) Only (ii) is True ✓

   (c) Both (i) and (ii) are True

   (d) Both (i) and (ii) are False

5. Consider the following statements:

   (i) The lower–bound time–complexity of comparison based sorting algorithms is $\Omega(n \cdot \log n)$.

   (ii) Radix sort is not a comparison based sorting algorithm.

   (a) Only (i) is True

   (b) Only (ii) is True

   (c) Both (i) and (ii) are True ✓

   (d) Both (i) and (ii) are False

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For the questions 6,7, and 8, assume we have a string with symbols a, b, c, d, e, f, where the frequencies of each symbol are given as 45, 13, 12, 16, 9, 5, respectively.

6. What is the Huffman code representation of character a?(Assuming the left child is assigned a 0 and right child is assigned a 1)

   (a) 110 (b) 1101 (c) 0 ✓ (d) 1100

7. How many bits are used to represent the character d with Huffman coding?

   (a) 2 (b) 3 ✓ (c) 4 (d) 5

8. What is the total number of bits required represent the Huffman encoded string S ?

   (a) 180 (b) 324 (c) 224 ✓ (d) 270

9. What is the time complexity for Huffman coding if we use the heap data structure and number of symbols in the alphabet is n?

   (a) $O(n^2)$ (b) $O(n^3)$ (c) $O(n \log n)$ ✓ (d) $O(n)$

10. Which of the following is true about greedy algorithms?

    (a) They choose the most appropriate decision at the moment without worrying about the future. ✓

    (b) They look through all possible decisions in an efficient manner and then pick the optimal one.

    (c) They always guarantee an optimal solution.

    (d) They divide the problem into smaller sub-problems.

11. Which of the following is a property of a max-heap?

    (a) The root node is the smallest value in the heap

    (b) The parent node is always greater than or equal to its child nodes ✓

    (c) The left child node is always greater than or equal to the right child node

    (d) The rightmost element at the lowest level is the minimum element.

12. Bob writes a sorting function that starts by finding the minimum of a list and swapping it to the beginning of the list. It then finds the minimum element from the remaining part of the list and swaps it with the second element. This process then continues until the entire list is in sorted order. Which sorting algorithm did Bob use?

    (a) Bubble Sort.

    (b) Selection Sort.✓

    (c) Insertion Sort.

    (d) None. Bob's algorithm is completely new.

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13. A priority queue is implemented with a Max-Heap. The level-order (breadth-first) traversal of the heap is: 10, 8, 5, 3, 2. Two new elements 1 and 7 are inserted into the heap in that order. The level-order traversal of the heap after the insertion of the elements is

    (a) 10, 8, 7, 3, 2, 1, 5 ✓

    (b) 10, 8, 7, 2, 3, 1, 5

    (c) 10, 8, 7, 1, 2, 3, 5

    (d) 10, 8, 7, 5, 3, 2, 1

14. Assume that the algorithms considered here will sort the input sequences in ascending order. If the input is already sorted in ascending order, which of the following are TRUE?

    I. Quick sort runs in $\Theta(n^2)$

    II. Bubble sort runs in $\Theta(n^2)$

    III. Merge sort runs in $\Theta(n)$

    IV. Insertion sort runs in $\Theta(n)$

    (a) I and II only

    (b) I and III only

    (c) II and IV only

    (d) I and IV only ✓

15. We have a list of tasks each with a start and finish time during the day. We would like to accomplish maximum number of tasks, and therefore, run a greedy interval scheduling algorithm to find the answer. Which one of the following should be used to sort the input task list to reach the optimum answer?

    (a) The starting times of the tasks

    (b) The finishing time of the tasks ✓

    (c) The duration of the tasks

    (d) We cannot reach the optimum with the greedy approach here.

16. While answering the predecessor and successor queries on an integer array using a bit-vector and R/S dictionaries constructed over that bit vector, which of the following will give the successor of k where k is the value of an item that is known to be present in the array?

    (a) select(rank(k)+1) ✓

    (b) select(rank(k+1))

    (c) select(rank(k))

    (d) select(rank(k-1))

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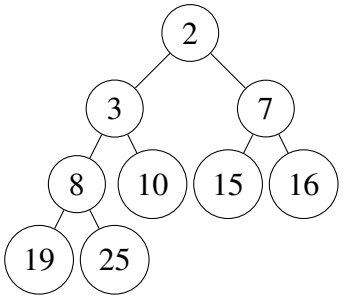
17. Time complexity to create a heap from an array of n elements is?

    (a) $O(n)$ (b) $O(logn)$ (c) $O(nlogn)$ ✓ (d) $O(n^2)$

18. What would be the new value of the root node after deleting the root node (value 2) from the following min heap?



    (a) 25 (b) 3✓ (c) 7 (d) 19

19. For the bit stream 0 1 0 1 1 1 0 0 1 0 0 1 0 0 1, what is $Rank_1(7)$?

    (a) 5 (b) 4 ✓ (c) 3 (d) 6

20. For the bit stream 0 1 0 1 1 1 0 0 1 0 0 1 0 0 1, what is $Select_1(4)$ assuming we are using a **1-based indexing** (the first position has index 1, and the last position has index 15) ?

    (a) 4 (b) 6 ✓ (c) 5 (d) 8

21. How is the binary code assigned to each element in a sequence when constructing a wavelet tree?

    (a) By sorting the elements and assigning a binary code based on their order.

    (b) By using a hash function to map each element to a binary code.

    (c) By comparing each element to the median value of the sequence and assigning a binary code based on its relative position.

    (d) By dividing the range of possible values into two halves and assigning a binary code based on whether the element falls in the first or second half. ✓

22. For the array shown in figure, how do we find the predecessor of 6 using rank/select queries?

1	2	3	4	5	6	7	8	9	10
1	0	1	0	1	0	1	1	1	1

    (a) select(rank(6)) (b) rank(6) + 1 (c) select(rank(6) - 1) ✓ (d) rank(6-1)

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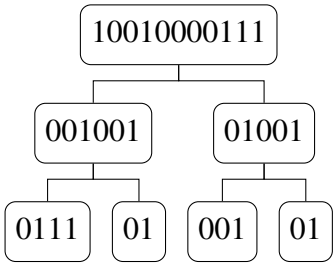
Answer questions 23, 24 and 25 according to the wavelet tree constructed over the sequence $S[1..11]$, where the symbols of S are from the alphabet $A = \{a,b,c,d,e,f,g,h\}$. At each node, the alphabet is split into two equal parts following the lexicographical order, e.g., on the root bitmap 0s represent $\{a,b,c,d\}$ and 1s represent $\{e,f,g,h\}$. Left subtree is the 0 link, and right is devoted to 1s.



23. What is string $S[1..11]$?

    (a) `e a c g d b a c e f h`

    (b) `f a b h c a a d f e g`

    (c) `e a b g c b b d e f h` ✓

    (d) `f a c h d a b c f e g`

24. Assume we are trying to retrieve $S[5]$, the fifth symbol, from the wavelet tree. What should be the correct values to be written in place of `A,B,C,D,E,F,G,H` in the following paragraph describing this operation ?

    "$S[5]$ is represented by a `A` bit on the root bitmap, which is the `B` `A` bit. So, we go to the `C` child, and check the `B` bit position, which is a `D` bit. This is the `E` `D` bit, so we move to the `F` child of this node and check the `E` bit, which is `G`. We know that zero represents symbol `H`, which is the $S[4]$, we are trying to access."

    (a) `A = 0, B = 3rd, C = left , D = 1, E = 1st, F = right, G = 1, H = c` ✓

    (b) `A = 1, B = 2nd, C = right, D = 1, E = 2nd, F = right, G = 1, H = g`

    (c) `A = 0, B = 3rd, C = left , D = 1, E = 1st, F = left , G = 1, H = c`

    (d) `A = 1, B = 2nd, C = right, D = 1, E = 2nd, F = right, G = 1, H = g`

25. Now, assume we are trying to find the 4th smallest element on the queried range $S[7..11]$. What should be the values `A,B,C,D,E,F,G,H` on the following?

    1) $\ell = 7$, $r = 11$, $k = 4$ on the root bitmap, and we move to the `A` subtree.

    2) Now, $\ell =$`B` , $r =$`C`, $k =$`D` on the current node, and we move to the `E` subtree.

    3) Now, $\ell =$`F`, $r =$`G`, $k =$`H` on the current node, and the answer becomes `f`.

    (a) `A:left , B = 1 , C = 6 , D = 4 , E:left , F = 1 , G = 4 , H = 2`

    (b) `A:right, B = 2 , C = 3 , D = 2 , E:left , F = 1 , G = 3 , H = 2` ✓

    (c) `A:left , B = 1 , C = 6 , D = 4 , E:left , F = 1 , G = 2 , H = 2`

    (d) `A:right, B = 2 , C = 3 , D = 2 , E:left , F = 1 , G = 2 , H = 2`