**Group Member Details**

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| Group Number | *G-21* |
| Registration Number of Group Members | 2020-CS-137  2020-CS-142 |

**Sorting Algorithms**

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| ***Insertion Sort*** |  |
| Description | *Insertion sort is one of the simplest type of sorting as sorting is done by iterating through the array using a key value every time a single key is selected and after iterate through the whole array the exact location of that particular key is found and hence one element is sorted in the same manner the whole the array is sorted in ‘n2’ iterations where n is the number of elements in array this sorting technique is simple but not suitable for large input as loop will be large and algorithm takes more time hence this algorithm is suitable for a limited input its implementation is simple we just take a key value usually 2nd element of array and iterate it through the array and compare it with all the index either it is larger or small then the neighbour index after finding its location the left side array is sorted and after all the loop iterations all the array is sorted although its a simple algorithm but it becomes so time consuming in its worst case as n2 time for n inputs if n becomes so larger the time of compilation becomes so large so this algorithm is only good for its best case but as new algorithms are found it is assumed that it can’t performs better than the advanced algorithm so it becomes useless as the same task is performed in less time.* |
| Pseudo code | *for j=2 to A.length( )*  *key=A[j]*  *i=j-1*  *while i>0 AND A[i]>key*  *A[i+1]=A[i]*  *i=i-1*  *A[i+1]=key* |
| Python code | *def insertion\_sort(arr):*  *for j in range(1, len(arr)):*  *key = arr[j]*  *i = j-1*  *while i >= 0 and key < arr[i] :*  *arr[i + 1] = arr[i]*  *i -= 1*  *arr[i + 1] = key* |
| Time Complexity Analysis | *C1: n*  *C2: (n-1)*  *C3: (n-1)*  *C4: Σn - 1j = 1(tj)*  C5: *Σn - 1j = 1 (tj - 1)*  C6: *Σn - 1j = 1(tj - 1)*  C7: *(n – 1)*  *Best Case: O(n)*  *Worst Case: O(n2)*  *Average Case: O(n2)* |
| Proof of correctness | * ***Initlization:***   *The first sub array is of one element and one element is assumed to be sorted*   * **Maintenance *:***   *The iteration of loop increase the size of sub array and when new element enters the array it will maintain the sorting property of sub array it is inserted where it is larger than its left one element*   * ***Termination:***   *The loop will be terminated when the sub array which is sorted to the size of actual array so the i indicated the size of original array.* |
| Strengths | * *Perform well for small no of inputs (best case)* * *Implementation is simple* * *Less space is required* |
| Weakness | * *As input is large it become time effective as n2 time is required* * *Not as efficient as other advanced algorithms* * *Need to iterate to all the array again and again* |
| Dry Run |  |

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| ***Merge Sort*** |  |
| Description | *Merge sort is one of the most respected algorithm used in data structures it is an algorithm which uses divide and conquer rule to sort an array this sorting in worst case uses O(n log n) time the working technique is that it simply divide an array into 2 parts and keeps on doing so until array contains only one element as one element is already sorted so the merge sort algorithm keeps on dividing the array into 2 parts recursively until array size becomes one then the merge sort use a merge function which combines (conquer) all the one sized array into single array that the resulted array is fully sorted hence we say that merge sort only divide the arras and the merge function actually combines them in an sorted array the biggest factor about merge sort is that in best case, in worst case and in average case it takes the same time which is O(n log n) as this time is much more good than O(n2) so that is the one reason to use merge sort rather then insertion sort as it doesn’t depends on number of inputs it have same effect either we use it for large input or for small as recursion use O(n log n) so in case we have small input it becomes little costly as due to divide and conquer (recursion) some space is required on each call so it take more space than insertion sort as a result it is better to use merge sort algorithm for sorting large data.* |
| Pseudo code | *Merge\_Sort(A,a,b)*  *if(a==b)*  *return*  *else*  *m=floor(a+b/2)*  *Merge\_Sort(A,a,m)*  *Merge\_Sort(A,m+1,b)*  *Merge\_Sort(A,b,m)*  *return*  *merg(A,p,q,r)*  *n1=q-p+1*  *n2=r-q*  *L = [0] \* (n1)*  *R = [0] \* (n2)*  *for i=0 to n1*  *L[i] = A[p + i]*  *for j=0 to n2*  *R[j] = A[q + 1 + j]*  *i=0*  *j=0*  *k=p*  *while i < n1 and j < n2*    *if(L[i]<=R[j])*  *A[k] = L[i]*  *i=i+1*  *else*  *A[k] = R[j]*  *j=j+1*  *k=k+1*  *while i < n1*  *A[k] = L[i]*  *i += 1*  *k += 1*  *while j < n2*  *A[k] = R[j]*  *j += 1*  *k += 1* |
| Python code | *def merg(A,p,q,r):*  *n1=q-p+1*  *n2=r-q*  *L = [0] \* (n1)*  *R = [0] \* (n2)*  *for i in range (0,n1):*  *L[i] = A[p + i]*  *for j in range(0,n2):*  *R[j] = A[q + 1 + j]*  *i=0*  *j=0*  *k=p*  *while i < n1 and j < n2:*  *if(L[i]<=R[j]):*  *A[k] = L[i]*  *i=i+1*  *else:*  *A[k] = R[j]*  *j=j+1*  *k=k+1*  *while i < n1:*  *A[k] = L[i]*  *i += 1*  *k += 1*  *while j < n2:*  *A[k] = R[j]*  *j += 1*  *k += 1*  *def mergeSort(A, p, r):*  *if((p<r)):*  *q=(p+r)//2*  *mergeSort(A,p,q)*  *mergeSort(A,q+1,r)*  *merg(A,p,q,r)* |
| Time Complexity Analysis | *Best Case: O(n log n)*  *Worst Case: O(n log n)*  *Average Case: O(n log n)* |
| Proof of correctness | * ***Initlization:***   *At start the k has value p and sub array is empty as k-p=0 so the smallest elopements’ of L and R are considered as smallest elements. A contains a single component which is inconsequentially assumed to be sorted*   * **Maintenance *:***   *If L[i]<=R[j] where L[i] is smallest element and not placed back to array so the increment in k and our own increment in i just to iterate through the right in sub array maintains the loop*   * ***Termination:***   *When k=r +1 the sub array have smallest elements in left and right arrays and the sub array is now sorted so after iterating to all the sub array the loop terminated* |
| Strengths | * *Take less time for large data as compared to other algorithms* * *It is a stable sort* * *Use divide and conquer technique rather than iteration* * *It is consistent in time not depends on input* |
| Weakness | * *Not efficient for small input as compared for other algorithms* * *Requires more space for temporary arrays* * *In best case ( array is sorted ) it goes to same process takes O(n log n) time* |
| Dry run |  |

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| ***Selection Sort*** |  |
| Description | *It is one of the simplest type of sorting algorithm which only based on iteration on loop in selection sort we just find the minimum element of the array and place it at the start of the array as if we are sorting in lower to higher format then the smallest element is placed at the first index of the array in traversing one time in array and finding the minimum of it we almost need n time so after finding the smallest element and placing it on first index our array becomes small and now we find minimum from remaining elements of the array and place them according to their appearance so basically what we are doing is we just dividing our array in two parts left side is filled with sorted array and the right side is with unsorted and un checked elements after placing all the elements we see that our array is sorted the smallest element is selected from the array and replaced with the leftmost number in that order the array is sorted either its a simple sorting algorithm but this is not sufficient for large input of data because its time complexity is O(n2) so on large number of input it doesn’t perform well so it is suitable for small number of inputs.* |
| Pseudo code | *for i = 1 to n - 1*  *min = i*  *for j = i+1 to n*  *if list[j] < list[min] then*  *min = j;*  *if indexMin != i then*  *swap list[min] and list[i]* |
| Python code | *def selection\_sort(A):*  *arr=[]*  *for i in range(len(A)):*  *min\_idx = i*  *for j in range(i+1, len(A)):*  *if A[min\_idx] < 0:*  *min\_idx = j*  *temp=A[i]*  *A[i]=A[min\_idx]*  *A[min\_idx]=temp* |
| Time Complexity Analysis | *C1: 1*  *C2: (n-1)*  *C3: (n-1)*  *C4: Σn - 1j = 1(n-j+1)*  C5: *Σn - 1j = 1 (n-j)*  C6: *Σn - 1j = 1(n-j)*  C7: *(n – 1)*  *Best Case: O(n2)*  *Worst Case: O(n2)*  *Average Case: O(n2)* |
| Proof of correctness | * ***Initlization:***   *At the start of the loop iteration the A[min index] is the smallest element of the array and i= min\_index*   * ***Maintenance:***   *The both loops maintains the loop invariant as in outer loop we iterate through the array and the inner loop checks for min value of array when A[i]<A[min\_index ] then min\_index is updated*   * ***Termination:***   *When the value of loop becomes equal to size of array then loop terminates after iterating and sorting all the elements in the array* |
| Strengths | * *Performance doesn’t affect by arrangement of data elements* * *Less operations are involved so where data movement is costly it is more economical* * *Simple to implement and understand* |
| Weakness | * *Less efficient as it takes O(n2) which is not good as compared to other algorithms* * *Worst case and bests case have no difference same time required* * *Not suitable for large data* |

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| ***Bubble Sort*** |  |
| Description | *Bubble sort is the simplest type comparison based algorithm that use loop iterations to iterate through the array and find appropriate place for every number it uses two loops so its time complexity is O(n2) which means that if the bubble sort is applied on large input then it will not work properly now let us see how the bubble sort works it will take an array and with iteration of outer loop picks an element and entered in inner loop the in inner loop it iterates through the whole array and select the bests appropriate place for this element once the element is settled then the loop terminates and it enters in outer loop and now take the next element from the array and elaterid the inner loop here the appropriate place for this element is found when all the elements settle down to their place then array is sorted it is also a comparison based sorting now let’s talk about is performance on large or small input it has worst case time complexity O(n2) so on large input it is not suitable in best case ( array is sorted ) it takes O(n) time which is its little benefit over selection and insertion sort.* |
| Pseudo code | *for i = 0 to loop-1 do:*  *swapped = false*  *for j = 0 to loop-1 do:*  *if list[j] > list[j+1] then*  *swap( list[j], list[j+1] )*  *swapped = true*  *if(not swapped) then*  *break* |
| Python code | *def bubbleSort(arr):*  *n = len(arr)*  *for i in range(n-1):*  *for j in range(0, n-i-1):*    *if arr[j] > arr[j + 1] :*  *arr[j], arr[j + 1] = arr[j+1],arr[j]* |
| Time Complexity Analysis | *C1: 1*  *C2: (n-1)*  *C3: Σn - 1j = 1(n-i+1)*  C4: *Σn - 1j = 1 (n-i)*  C5: *Σn - 1j = 1(n-i)*  *Best Case: O(n)*  *Worst Case: O(n2)*  *Average Case: O(n2)* |
| Proof of correctness | * ***Initlization:***   *Initially the A[n] is considered the smallest element*   * ***Maintenance:***   *The inner loop iterates through the array repeatedly and checks for the smallest elements with comparing with A[n] and n is decreasing then replace the element with its left size*   * ***Termination:***   *The loop termination depends on the condition when loop variable becomes equal to size of array means loop iterated through all the array and now array is sorted* |
| Strengths | * *Take less time is bests case ( sorted input )* * *Simple iterative strategy used* * *Less operations required data movement is not costly* * *Little memory overhead* * *Stable sorting algorithm* |
| Weakness | * *Takes more time as compared to other algorithms* * *Not suitable for large data* * *High number of swapping between elements* |
| Dry Run |  |

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| ***Quick Sort*** |  |
| Description | *Just like merge sort the quick sort also uses the divide and conquer approach to sort an array the divide and conquer strategy basically designed to save the time of cpu hence the time required to sort an array is less in quick sort the array is also divided on the basis of a pivot element the pivot may be selected randomly or it might be selected according to some rule like select first element as pivot or either select the last one or the median of array the main part of quick sort is partition function this function after iterating through the array place the pivot x on its appropriate sorted location and after that it place all the elements small then pivot to left of that array and then the large elements to right of the array then quick sort recursively sort the array on the partitioned left and right arrays now talk about the time it have best case time O(n log n) and same for average case but for worst case( array is sorted ) it takes O(n2) time which is not suitable so it doesn’t performs well in its worst case.* |
| Pseudo code | *quickSort(arr[], low, high)*  *{*  *if (low < high)*  *{*  *pi = partition(arr, low, high);*  *quickSort(arr, low, pi - 1 )*  *quickSort(arr, pi + 1, high )*  *}*  *}*  *partition (arr[], low, high)*  *{*  *pivot = arr[high];*  *i = (low – 1)*  *for (j = low; j <= high- 1; j++)*  *{*  *if (arr[j] < pivot)*  *{*  *i++;*  *swap arr[i] and arr[j]*  *}*  *}*  *swap arr[i + 1] and arr[high])*  *return (i + 1)* |
| Python code | *def partition(arr,low,high):*  *pivot=arr[high]*  *i=(low-1)*  *for j in range(low, high):*  *if arr[j] <= pivot:*  *i = i+1*  *temp=arr[i]*  *arr[i]=arr[j]*  *arr[j]=temp*    *temp=arr[i+1]*  *arr[i+1]=arr[high]*  *arr[high]=temp*  *return (i+1)*  *def quickSort(arr,low,high):*  *if(low<high):*  *pi=partition(arr, low, high)*  *quickSort(arr, low, pi - 1)*  *quickSort(arr, pi + 1, high)* |
| Time Complexity Analysis | *Best Case: O(n2)*  *Worst Case: O(n log n)*  *Average Case: O(n log n)* |
| Proof of correctness | * *Initlization:*   *Initially the pivot is set randomly and then the elements are compared with it*   * *Maintenance:*   *The loop is responsible for partition of the array the partition is done by comparing all the elements of loop with the pivot and the smallest element will be on left size of array he large elements on right of the array*   * *Termination:*   *The termination condition is simply when the low(first) becomes equal to high (last) index of the array* |
| Strengths | * *Use divide and conquer technique* * *Efficient for best and average case time is O(n log n)* * *It is able to deal well with a huge list of items.* * *No additional space required* |
| Weakness | * *Its worst case will perform same as insertion selection sort* * *If array is already sorted it is not suitable* * *If pivot is not selected well the time complexity will be affected* |

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| ***Bucket Sort*** |  |
| Description | *Bucket sort is an interesting sorting algorithm in which an un sorted elements of array are placed into a bucket according to their weight the bucket is formed according to the range of the max number in the array then the number are placed in form of count in the respective bucket for e.g. if largest element in array id 60 then we form buckets of 60 size and place all the elements at the index equal to them at last all the sorted buckets are combined and a sorted array is formed its very simple but it have some disadvantages that if the largest element eve if one of them is very large then we need a large space to create the bucket also its time complexity is so varying that in normal case it is O(n) in best case it is O(n+k) and in worst case it becomes O(n2) the worst case is that all the elements in array are supposed to enter at same bucket it doesn’t depends on number of input rather it depends on the max of them it can’t applied on all data types it only work with integers* |
| Pseudo code | *bucketSort(array, k)*  *buckets = new array of k empty lists*  *M = max(array)*  *for i = 1 to length(array)*    *buckets[floor(k × array[i] / M)].append(array[i])*  *for i = 1 to k do*  *nextSort(buckets[i])*  *return buckets* |
| Python code | *def bucketSort(array):*  *bucket = []*    *for i in range(len(array)):*  *bucket.append([])*  *for j in array:*  *index\_b = int(10 \* j)*  *bucket[index\_b].append(j)*  *for i in range(len(array)):*  *bucket[i] = sorted(bucket[i])*  *k = 0*  *for i in range(len(array)):*  *for j in range(len(bucket[i])):*  *array[k] = bucket[i][j]*  *k += 1*  *return array* |
| Time Complexity Analysis | *Best Case: O(n+k)*  *Worst Case: O(n2)*  *Average Case: O(n)* |
| Proof of correctness |  |
| Strengths | * *As buckets are individual arrays so to sort them is more easy* * *Abel to use an external sorting algorithm* * *On best case it performs well also in average case* |
| Weakness | * *Need more spaces as the max in array increases the bucket sixe increases* * *In worst case it is not suit able as it take O(n2) time* * *Can’t work with all data types only integer* * *Performance depends on number of buckets* |

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| ***Radix Sort*** |  |
| Description | *Radix sort is a sorting algorithm which sorts the elements in a linear time as it comes under the category which sorts in the linear time. Radix sort uses counting sort as base and then sort the element. In radix sort, elements are sorted digit by digit from least significant to most significant digit. After every iteration, next significant digit is sorted keeping in view the order which starts from tens then hundreds and so on.* |
| Pseudo code | *Radix\_Sort(A,d)*  *1- for i = 1 to d*  *2- use a stable sort to sort array A on digit i* |
| *Python Code* | *def CountSort(A):*  *max = int (FindMax(A))*  *length=len(A)*    *C= [0 for i in range (max+1)]*  *B= [0 for i in range (length)]*    *for j in range (0, len(A)):*    *C[A[j]] =C[A[j]] +1*    *for i in range (0, len(C)):*  *C[i]=C[i]+C[i-1]*    *i = length -1*  *while i >= 0:*  *C[A[i]]-=1*  *B[C[A[i]]-1] = A[i]*  *i -= 1*  *return B*  *def RadixSort(A):*    *maximum=FindMax(A)*  *Base=1*  *while maximum // Base>0:*  *B = CountSort(A)*  *Base \*=10*  *print(B)* |
| *Time Complexity Analysis* | *Best Case: O (n + k)*  *Worst Case: O (n + k)*  *Average Case: O (n + k)* |
| Proof of correctness | *Initlization:*  *The correctness of radix sort follows by induction on the column being sorted Maintenance*  *Maintenance:*  *The analysis of the running time depends on the stable sort used as the intermediate sorting algorithm. When each digit is in the range 0 to k, so that it can take on k possible values), and k is not too large, counting sort is the obvious choice. Each pass over n d-digit numbers then takes time. n C k.*  *Termination:*  *There are d passes, and so the total time for radix sort is d\*n C k. When d is constant and k D O.(n), we can make radix sort run in linear time. More generally, we have some flexibility in how to break each key into digits.* |
| Strengths | 1. *When there are less elements, this radix sort is fast.* 2. *Radix sort is used in suffix array construction.* 3. *Radix Sort is also called stable sort.* |
| Weakness | 1. *Radix sort is not flexible, it needs to be re written for every different data type.* 2. *Extra space is required for this algorithm.* |

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| ***Counting Sort*** |  |
| Description | *Counting sort is also a sorting algorithm that sorts an array of elements in the linear time. In this algorithm, an array is first analysed and the maximum element is found in an input array. A new array is made of the size of the maximum element in an input array. All the digits in the array are counted and placed in the temporary array after counting each of them. Now, the adjacent elements are added and stored on the index. At the last, we iterate through the input array and check all the digits one by one and stores the sorted array in a new array C.* |
| Pseudo code | Counting\_Sort(A,B,k)  1 let C [ 0..k ] be a new array  2 for i = 0 to k  3 C=[i] = 0  4 for j = 1 to A.length  5 C[A[j]] = C [A[J]] + 1  6 // C[i] now contains the number of elements equal to i.  7 for i = 1 to k  8 C[i]= C[i] +C[i-1]  9 // C[i] now contains the number of elements less than or equal to i. 10 for j = A. length **down to** 1  11 B[C[A[j]]] = A[j]  12 C[A[j]] =C[A[j]]- 1 |
| Python Code | def CountSort(A):      max = int(FindMax(A))      length=len(A)        C=[0 for I in range (max+1)]      B=[0 for i in range (length)]      for j in range(0,len(A)):            C[A[j]]=C[A[j]]+1      for i in range(0,len(C)):          C[i]=C[i]+C[i-1]      i = length -1      while i >= 0:          C[A[i]]-=1          B[C[A[i]]-1]=A[i]          i -= 1      return B |
| Time Complexity Analysis | *Best Case: O(n)*  *Worst Case: O(k)*  *Average Case: O(n+k)* |
| Proof of correctness | * *Initialization:*   *After the for loop of initializes the array C to all zeros, the for loop of lines 4–5 inspects each input element.*   * *Maintenance:*   *If the value of an input element is i, we increment C[i]. Thus, C[i]. holds the number of input elements equal to.* |
| Strengths | 1. *The running time of counting sort is O(n), when the length of the input array is not much smaller.* 2. *In counting sort, there is no comparison between elements.* 3. *Better for small range of elements.* |
| Weakness | 1. *It’s not good for large number of input.* 2. *Counting sort uses linear sort.* 3. *If input is very large, this algorithm does not work on it.* |

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| ***Tree Sort*** |  |
| Description | *Tree sort is a sorting algorithm which uses some kind of tree like binary search tree to sort an input array. First of all, a binary search tree is made till the number of the inputs, after that the tree is traversed using in order traversal method on the tree and after performing all the above-mentioned steps, a sorted array is returned as output.* |
| Pseudo code | 1. *Input array* 2. *Make a binary search tree* 3. *Make an in-order traversal* |
| Python Code | *class Node:*  *def \_\_init\_\_(self, key):*  *self.key = key*  *self.left = None*  *self.right = None*  *self.parent = None*    *def insert(self, node):*  *if self.key > node.key:*  *if self.left is None:*  *self.left = node*  *node.parent = self*  *else:*  *self.left.insert(node)*  *elif self.key <= node.key:*  *if self.right is None:*  *self.right = node*  *node.parent = self*  *else:*  *self.right.insert(node)*    *def inorder(self):*  *if self.left is not None:*  *self.left.inorder()*  *print(self.key, end=' ')*  *if self.right is not None:*  *self.right.inorder()*      *class BSTree:*  *def \_\_init\_\_(self):*  *self.root = None*    *def inorder(self):*  *if self.root is not None:*  *self.root.inorder()*    *def add(self, key):*  *new\_node = BSTNode(key)*  *if self.root is None:*  *self.root = new\_node*  *else:*  *self.root.insert(new\_node)*      *bstree = BSTree()*    *alist = input('Enter the list of numbers: ').split()*  *alist = [int(x) for x in alist]*  *for x in alist:*  *bstree.add(x)*  *print('Sorted list: ', end='')*  *bstree.inorder()* |
| Time complexity Analysis | *Best Case: O(n log n)*  *Worst Case: O(n2)*  *Average Case: O(n)* |
| Strengths | 1. *Sorting in Tree sort algorithm is as fast as quick sort algorithm.* 2. *Like a linked list, in tree sort algorithm changes are vesy to make.* |
| Weakness | 1. *If the array is already sorted, worst case occurs.* 2. *In worst case, O(n^2) is the running time.* |