



ARC Sort: Enhanced and Time Efficient Sorting Algorithm

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ABSTRACT

This paper discusses about a sorting algorithm which uses the concept of buckets where each bucket represents a certain number of digits. A two dimensional data structure is used where one dimension represents buckets i.e; number of digits and each bucket's corresponding dimensions represents the input numbers that belong to that bucket. Each bucket is then individually sorted. Since every preceding bucket elements will always be smaller than the succeeding buckets no comparison between them is required. By doing this we can significantly reduced the time complexity of any sorting algorithm used to sort the given set of inputs.

Keywords

Sorting, Bucket, Enhanced Selection, ARC Sort

1. INTRODUCTION

One of the most recurrent problems in the field of computer science is sorting a list of items, numbers or strings. It refers to the arranging of numerical or alphabetical or character data in statistical order (either in increasing order or decreasing order) or in lexicographical order (alphabetical value like addressee key) [1-3]. Computer Applications routinely use sorting before implementing search, merge or normalize functions. The most commonly used algorithms like Bubble Sort [4], Selection Sort & Insertion Sort are time consuming unlike the enhanced versions which are considered as complex algorithms. There is a positive correlation between complexity and effectiveness of an algorithm [5]. Hence, much work is being done to improve the efficiency of algorithms and allocation of resources, as execution of comparisons, swaps and assignment operations are involved in sorting algorithms.

Complexity of programming, computation & storage besides presence of pre-sorted data affect the choice of sorting algorithm to use.

Our purpose behind using ARC sort is to reduce the number of iterations required to sort the given number of elements. Reduce the number of unnecessary comparisons and swaps which will optimize any sorting algorithm. We divide the array of input numbers by placing them in a bucket. This bucket corresponds to the number of digits present in the input element. This will reduce the number of unnecessary comparisons by a fair bit and will certainly reduce the number of swaps.

2. ENHANCED SELECTION SORT

In enhanced selection sort, first the maximum element amongst all the other elements of the array is placed in its right position. In every iteration after finding the maximum element the size of the array is reduced by 1. Enhanced selection sort is better than selection sort because it reduces the number of swaps needed to sort the elements, this makes the algorithm more stable. The time complexity remains the same as that of selection sort that is $O(n^2)$ [7].

Procedure for enhanced selection sort

1. Call enhanced selection sort function with the input array and its size
2. Find the maximum element and place it in its correct position
3. Decrement the size by 1
4. Call enhanced selection sort function recursively with the reduced size

3. CONCEPT OF ARC SORT

Consider a two dimensional array $A[][]$ with k number of columns and n number of rows

Where,

k - pre-estimated highest number of digits amongst the given input numbers

n - number of input numbers

Another array $index[]$ of length k which indicates that how many numbers are present in each bucket of array $A[][]$

Consider a value of k which represents the highest number of digits

For each input number calculate the number of digits. Now store that number at the bucket corresponding to the number of digits. Increment the array $index[]$ whose position is represented by number of digits. Repeat this process for each input number and populate each input number in its appropriate position. If the input array contains negative numbers dedicate one bucket for all the non-positive numbers. Now since negative numbers are also present, the first bucket is reserved for those numbers that is the 0th bucket. In general, if a number has m number of digits it will be placed in m^{th} bucket of array $A[][]$

Once all the input numbers are placed in buckets, now sort each bucket individually using Enhanced Selection sort. The purpose of dividing each element into buckets of number of digits is it reduces the number of passes needed to sort an array.



The other purpose of dividing the array of given input numbers is that every i^{th} bucket numbers will always be less than all the numbers present in j^{th} bucket where $i < j$ that is every preceding bucket elements will always be smaller than all its succeeding buckets. This reduces the sorting task by a huge margin. If the input numbers are of different ranges dividing the input array will help increase the efficiency of the sorting algorithm used.

4. FLOW CHART

Below is the flow chart for the ARC algorithm

Terms used,

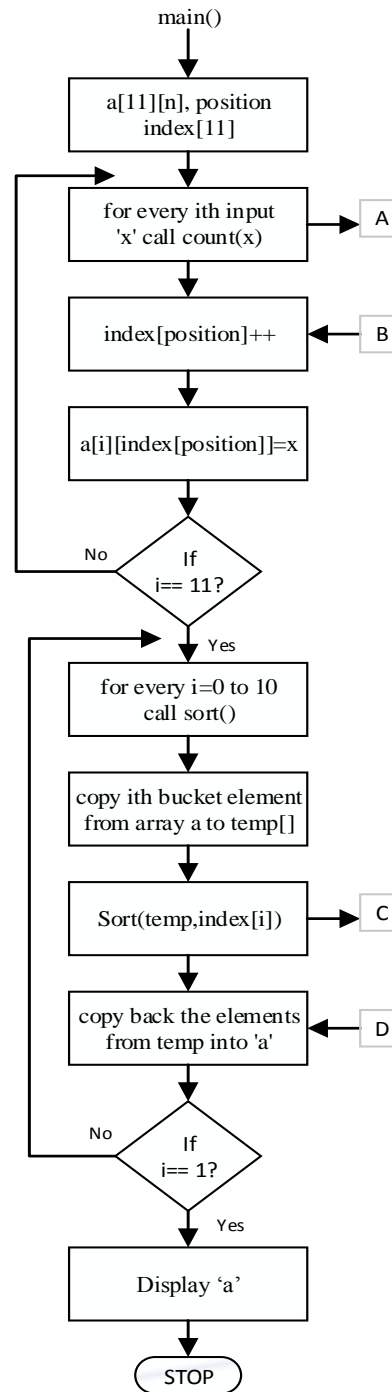
Main() – represents code present in main function of the program

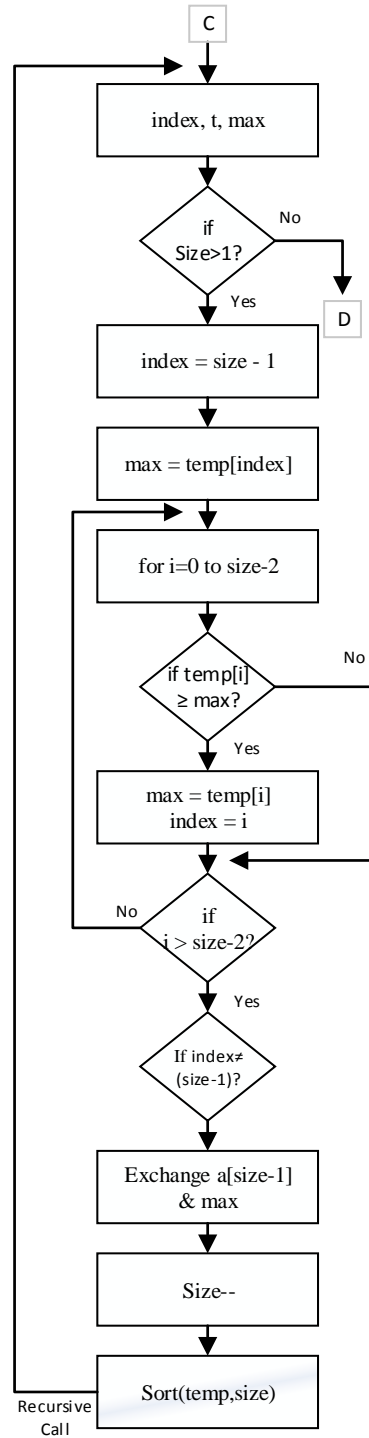
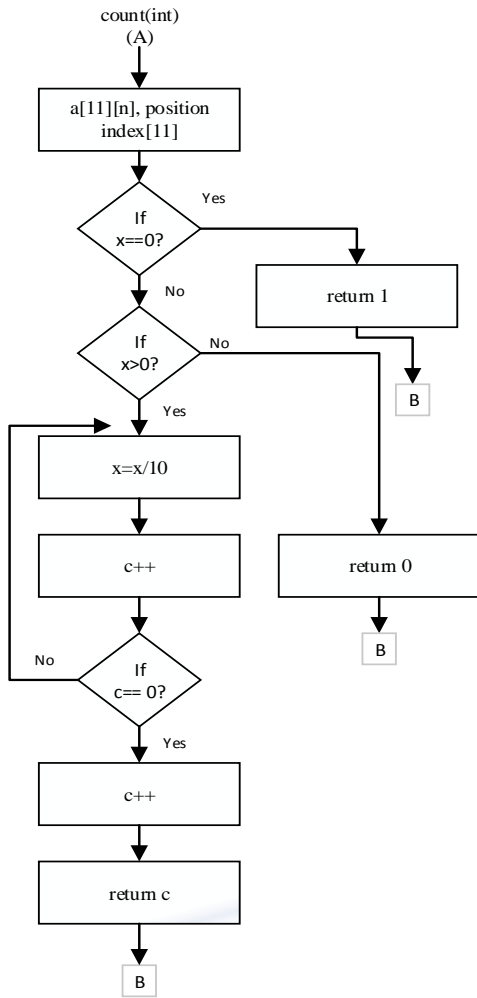
Label A – call to count(int) function which computes the number of digits present in the given integer

Label B – return back to calling function i.e main()

Label C – call to sort(int [],int) function to sort the given array

Label D – return back to calling function i.e main()





5. Pseudo Code

Terms: x – current input element , k – number of digits of max number, $index[k]$ – every element initialized to -1 , $a[k][n]$

main()

1. For $i=0$ to $n-1$
2. $Position = count(x)$ // *count* is function which will calculate the number of digits of x
3. $Index[position]++$;



```

4. a[position][index[position]]=x
5. end for
6. for i=0 to k
7. if(index[i]>0)
8. sort(a[i][],index[i])
9. end if
10. end for
  
```

```

sort(a[[]],size)
  
```

```

1. if(size>1)
2. index=size-1;
3. max=a[index]
4. for i=0 to size-2
5. if(a[i]>=max)
6. max=a[i]
7. index=i
8. end if
9. end for
10. if(index!=size-1)
11. temp=a[size-1]
12. a[size-1]=max
13. a[index]=temp
14. end if
15. size =size -1
16. sort(a,size)
17. end if
  
```

6. Example

Input:

349	34	-72	22	14	-1
0	1	2	3	4	5

Consider

K = 5 = highest number of digits present in the data set.

M = 6 = no. of elements

A[5][6]

Index[6]

For E(i=0 to 5)

Index[i] = -1

1) X = a[0] //input element when i=0

X = 349

position = count(X), //count() will calculate the numbers of digits present in the number

position = 3 // since x=349 contains 3 digits

index[position]++ // increment the count for the corresponding bucket in this case bucket 3

a[position][index][position] = X, //place the input number in its appropriate position

index[]					
-1	-1	-1	0	-1	-1
0	1	2	3	4	5
a					
	0	1	2	3	4
0				349	
1					
2					
3					
4					
5					
6					

2) X = a[1] // input element

X = 34

position = count (X);

position = 2;

index[position] ++;

a[position][index][position] = X;

index[]					
-1	-1	0	0	-1	-1
0	1	2	3	4	5
a					
	0	1	2	3	4
0			34	349	
1					
2					
3					
4					
5					
6					

3) X = a[2]

X = -72

position = count (X);

position = 0; //since the input number is negative its bucket is reversed that is the 0th bucket

index[position] ++;

a[position][index][position] = X;

index[]					
0	-1	0	0	-1	-1
0	1	2	3	4	5
a					
	0	1	2	3	4
0	-72		34	349	
1					
2					
3					
4					
5					
6					

4) X = a[3]

X = 22

position = count (X);

position = 2;

index[position] ++;

a[position][index][position] = X;

index[]					
0	-1	1	0	-1	-1
0	1	2	3	4	5



a	0	1	2	3	4
0	-72		34	349	
1			22		
2					
3					
4					
5					
6					

```
5) X = a[4]
X = 14
position = count (X);
position = 2;
index[position] ++;
a[position][index][position] = X;
```

index []	0	1	2	3	4	5
0	-1	2	0	-1	-1	
1						

a	0	1	2	3	4
0	-72		34	349	
1			22		
2			14		
3					
4					
5					
6					

```
6) X = a[4]
X = 14
position = count (X);
position = 2;
index[position] ++;
a[position][index][position] = X;
```

index []	0	1	2	3	4	5
0	-1	2	0	-1	-1	
1						

a	0	1	2	3	4
0	-72		34	349	
1			22		
2			14		
3					
4					
5					
6					

```
7) X = a[5]
X = -1
position = count (X);
position = 0;
index[position] ++;
a[position][index][position] = X;
```

index []	1	2	3	4	5
0	-1	2	0	-1	-1
1					

a	0	1	2	3	4
0	-72		34	349	
1	-1		22		
2			14		
3					
4					

a	0	1	2	3	4
5					
6					

```
Sort ( )
i) index[0] > 0 // since the number of elements present in 0th
bucket are greater than 0 the elements need to be sorted
sort (a[0][ ],index[0]) // call function sort with the 0th bucket
elements are the size indicated by the index array
```

Output:

a	0	1	2	3	4
0	-72		34	349	
1	-1		22		
2			14		
3					
4					
5					
6					

```
ii) index [1] = -1 // since no elements are present in the 1st
bucket sort function will not be called
skip
```

```
iii) index [2] > 0
sort (a[2][ ], index[2])
output:-
```

a	0	1	2	3	4
0	-72		14	349	
1	-1		22		
2			34		
3					
4					
5					
6					

```
iv) index [3] = 0 // since only 1 element is present in the 3rd
bucket sorting is not required therefore skip this iteration
skip
```

```
v) index [4] = -1
skip
```

Display Array “a” bucket wise

-72	-1	14	22	34	349
0	1	2	3	4	5

7. Performance Analysis

7.1 Best Case

If $k=n$, where k - number of digits of maximum element in the data set & n - number of data elements in the data set and If every bucket has exactly one element, the time complexity of the ARC algorithm is,

$$T(n) = O(n^2/k) \\ = O(n^2/n) \\ = O(n)$$

7.2 Average Case

If there are k buckets and each bucket contains equal number of elements that is,

Each bucket contains n/k elements

Time complexity of ARC algorithm becomes,



$$T(n) = O(n^2/k^2)$$

7.3 Worst Case

If there are k buckets present but all the elements in the data set belong to the one particular bucket

Therefore the time complexity of ARC algorithm becomes same as that of Modified Selection Sort

$$T(n) = O(n^2)$$

Table 1: Comparison with other Sorting algorithm

	ARC Sort	Insertion Sort	Selection Sort	Bubble Sort
Best Case	$O(n)$	$O(n)$	$O(n^2)$	$O(n^2)$
Average Case	$O(n^2/k)$	$O(n^2)$	$O(n^2)$	$O(n^2)$
Worst Case	$O(n^2)$	$O(n^2)$	$O(n^2)$	$O(n^2)$

Where, k- number of buckets

Table 2: Execution Time Comparison

No. of Elements	Elapsed Time (ms)			
	ARC Sort	Selection Sort	Insertion Sort	Bubble Sort
1,000	10	18	17	15
5,000	13	59	26	65
10,000	31	207	53	65
20,000	126	743	141	841

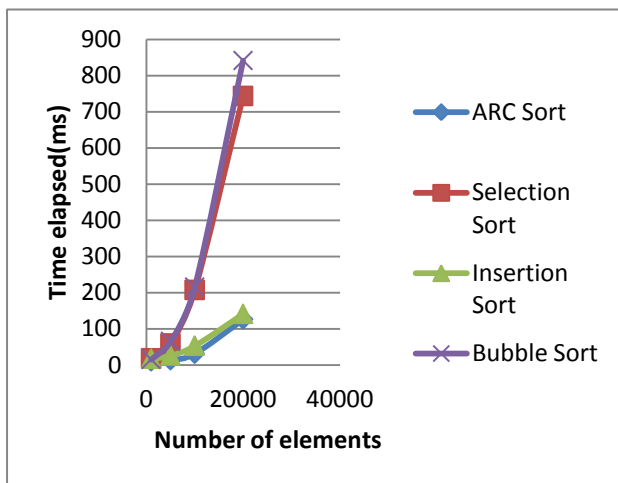


Fig 1 : Elapsed time comparison for various sorting algorithms

The above table & figure represents the comparison of ARC Sort with Selection, Insertion and Bubble Sort. The left hand side column is the number of elements required to be sorted. For each number of elements the given sorting algorithms are run. The corresponding time taken by each algorithm is as shown above. The input set used to sort was taken randomly & the average value of each run was taken as the actual time of execution.

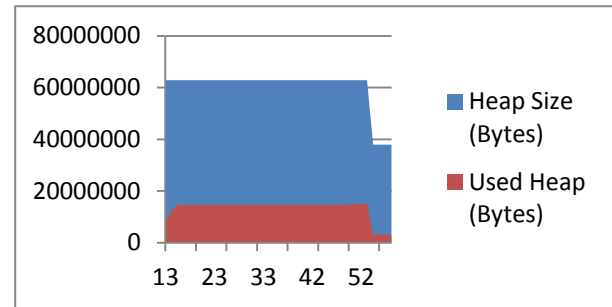


Fig 2 : Memory Heap

The above graph shows Memory heap used and allocated. The maximum heap allocated was greater than 60MB but the maximum amount of heap used is greater than 10MB but less than 15MB. The y-axis of the graph shows the amount of heap used, whereas the x-axis of the graph shows the amount of time elapsed.

8. CONCLUSION

The paper presents the concept & implementation of ARC Sort which not only reduces the running time as compared to Selection Sort, Insertion Sort and Bubble Sorting but is also efficient in performance as it reduces the number of unnecessary comparison and swaps by making use of 2 Dimensional Arrays.

9. REFERENCES

- [1] I. Flores, "Analysis of Internal Computer Sorting", ACM, vol. 7, no. 4, (1960), pp. 389- 409..
- [2] G. Franceschini and V. Geffert, "An In-Place Sorting with $O(n \log n)$ Comparisons and $O(n)$ Moves", Proceedings of 44th Annual IEEE Symposium on Foundations of Computer Science, (2003), pp. 242-250.
- [3] D. Knuth, "The Art of Computer programming Sorting and Searching", 2nd edition, Addison-Wesley, vol. 3, (1998).
- [4] Astrachanm O., Bubble Sort: An Archaeological Algorithmic Analysis, Duke University, 2003
- [5] C. A. R. Hoare, Algorithm 64: Quick sort. Comm. ACM, vol. 4, no. 7 (1961), pp. 321
- [6] An Enhancement of Major Sorting algorithms, Jihad Alnihoud and Rami Mansi, Department of Computer Science, Jordan.