Use-Me Sort: A new Sorting Algorithm

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ABSTRACT
One of the fundamental issues in Computer Science is the ordering of a list of items - known as sorting. Sorting algorithms such as the Bubble, Insertion and Selection Sort, all have a quadratic time complexity $O(N^2)$ that limits their use when the number of elements is very large.

This paper presents Use-Me sort. It sorts a list by making the use of already sorted elements present in the list. Moreover, it provides a trade-off between Space and Time Complexity with better performance than the existing sorting algorithms of the $O(N^2)$ class.

General Terms
NOC - Number of Comparisons, Space complexity, Time Complexity.

Keywords
Algorithm, Complexity, Insertion Sort

1. INTRODUCTION
Information is growing rapidly in today’s world and to search for this information, it should be systematically organized. Algorithms such as Bubble, Insertion and Selection Sort, have an $O(N^2)$ time complexity that limits its usefulness to small number of elements no more than a few thousand elements.[5]

This paper presents Use-Me Sort which makes use of already sorted elements present in the array. It iterates from one end to the other, leaving behind a sorted array. Whenever a group of ordered elements is encountered, it is merged recursively with the sorted array behind. It follows a methodology, similar to Insertion Sort.

The aim of Use-Me sort is to reduce the Number of Comparisons (NOC) by using binary search instead of linear search – at the time of merging. The difference is not big for small N but it becomes significant when N goes high to some few ten thousand elements or more.

For further references, we will use a term called UM array for Use-Me array. In an unsorted array, UM array refers to an ordered sub-array which is out of order with respect to the array. It is important to note that the elements of the sub-array should be in some order. In Figure 1, if the array A[1..6] is to be sorted in ascending order then, array A[3..5] is a UM array.

Fig 1: Example of UM array

2. APPROACH
Use-Me Sort uses an approach which is as follows:
1) Iterate from the first element till the last to find a UM array.
2) Merge the UM array recursively with the sorted array behind.
3) Repeat the steps 1 and 2 till the end.

2.1 Pseudo Code
Input: Array A[0…N-1], N is length of the array.
Output: Array A[0…N-1] in ascending order.

```
USE-ME(A)
1   i←0
2   while i < N-1
3       if A[i] > A[i+1]
4           then k←i+1
5           while A[k] > A[k+1] and k < N-1
6               do k++
7           if k ≠ i+1
8               then m ← k-i-1
9               DESC(A, i, k, m)
10          i ← k
11    else
13           do k++
14           m ← k-i-1
15           ASC(A, i, k, m)
16    else
17       i++
```

DESC(A, i, k, m)
1   if m = -1
2   then return 0
3   temp ← A[i+m+1]
4   l ← DESC(A, i, k, m-1)
5   if temp < A[l]
6       then low ← -1
7   else
8       high ← i-1

}
2.2 Example

Consider the list as below:

2 3 5 4 3 1

STEP 1: Iterate from the first element to the last to find a UM array.

- As 5 < 4, set Indexes i = 3 and k = 4
  2 3 5 4 3 1
  i k

- Again 3 < 4, so k++
  2 3 5 4 3 1
  i k

- Again 1 < 3, so k++
  2 3 5 4 3 1
  i k

STEP 2: Recursively merge the already sorted array, A[1 to i] and UM array, A[i+1 to k]

2 3 5 4 3 1
k, p

temp = 1

p --

2 3 5 4 3 1
i p k

temp = 3

p --

2 3 5 4 3 1
i p k

temp = 4

p --

2 3 5 4 3 1
i p k

i = p, So return

Until A[i] > temp
Repeat A[k] = A[i]
k -- and i --

2 3 5 4 3 1
k

Now do, A[k] = temp
And return k --

2 3 5 4 3 1
k

Repeat the Above Process
and we get,

2 3 5 4 3 1
i k

Repeat the Above Process
and we get,

2 3 5 4 3 1
i k

Repeat the Above Process
and we get,
3. EVALUATION
3.1 Use of Binary Search
In Use-Me sort, the NOC is minimized by using binary search in merging two arrays. As we know the fact that, two arrays to be merged – will be already in order. Therefore binary search will be an effective way to minimize the NOC in merging the sub-arrays.

3.2 Trade-Off
It supports a Space-Time trade-off, in which run-time of an algorithm can be improved by making it use more memory or vice versa. To improve the runtime, we trade memory and for less memory usage we trade runtime.[2]
In Use-Me Sort, by restricting the size of the ordered sub-array, we can reduce the memory usage. As the memory decreases, the execution time (time to sort the array) will increase and hence, we can achieve Space-Time trade-off.

3.3 Stability
Stability simply means, maintaining the relative order of elements with equal value. In other words, a sorting algorithm is stable if whenever there are two records X and Y with the same value and with X appearing before Y in the original list, then X will always appear before Y in the sorted list. Use-Me algorithm is a stable algorithm.[8]

4. ANALYSIS
4.1 Complexity
The complexity of Use-Me algorithm is O(N) in the best case. In average case and worst case, when the UM array becomes small, the approximate complexity is O(Nlog(N)). This is because it will take N comparisons to iterate the array and utmost logN comparisons to find the correct location of an element of UM array. After summing all of it together the complexity becomes O(Nlog(N)). In case when the array is in decreasing order, the time complexity becomes less than O(Nlog(N)) because of the fact that the whole array will become UM array, apart from the first element. Therefore it will take operations, less than normal, to sort the array.

4.2 Comparison
When compared the proposed algorithm with Insertion Sort, it was inferred that the Use-Me algorithm shows a better results. The Table 1 given below shows the complexities of different sorting algorithms with the Use-Me algorithm[1]

Table 1. Comparison with other Algorithms

<table>
<thead>
<tr>
<th></th>
<th>Use-Me Sort</th>
<th>Bubble Sort</th>
<th>Selection Sort</th>
<th>Insertion Sort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Case</td>
<td>O(N)</td>
<td>O(N)</td>
<td>O(N)</td>
<td>O(N)</td>
</tr>
<tr>
<td>Complexity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>O(Nlog(N))</td>
<td>O(N)</td>
<td>O(N)</td>
<td>O(N)</td>
</tr>
<tr>
<td>Case Complexity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worst Case</td>
<td>O(Nlog(N))</td>
<td>O(N)</td>
<td>O(N)</td>
<td>O(N)</td>
</tr>
<tr>
<td>Complexity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The efficiency of the Use-Me sort algorithm will be measured in CPU time using the system clock [5] on a computer with minimal background processes running, with respect to the size of the input array, and compared with the insertion sort algorithm. Both the algorithms were executed with array size: 3k, 6k, 9k, 12k and 15k. The data sets used, include system generated random number. Algorithms were executed in C++.
A comparison graph of CPU time Vs Array Size of Use-Me sort with Insertion sort has been shown in Figure 2 below.

Fig 2: Comparison of Use-Me and Insertion Sort
The trade-off between Memory and Time Complexity is shown in Figure 3 below by a graph. This graph represents a comparison of Use-Me algorithm executed for a Data Set of 15000 elements for different allocated memory.

Fig 3: Comparison at different Allocated Memory

5. CONCLUSION
This paper introduced Use-Me Sort with Time Complexity O(Nlog(N)). It makes use of already ordered elements in the list and recursively merge them with the sorted list behind.

It also provides a trade-off between Memory and Time Complexity. This trade-off allows Use-Me sort to perform better for list having large number of elements.

In striking contrast, Bubble, Insertion and Selection sort have quadratic time complexity that limit its use to a small number of elements. Use-Me is slightly faster than insertion sort when N is small but is much faster as N grows.[5]

From the results in Table 1, Figure 1 and Figure 2, we conclude that Use-Me algorithm has performed well in average case because it avoids as well as reduces the number
of comparisons and number of swaps in comparison to the other algorithms.

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7. REFERENCES