

Sorting Algorithms

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1 Project Proposal

1.1 Goals

1.2 Plan

2 Sorts

2.1 Merge Sort

2.1.1 Algorithm

Merge sort is a comparison-based sorting algorithm, based on the divide-and-conquer design. Its average and worst cases are both $n \log(n)$, and its best case is $\Omega(n)$. Invented in 1945 by John von Neumann, it exploits the fact that combining two lists of sorted data is a linear-time process. [1]

2.1.2 Efficiency

The actual code for the algorithm is available in **Listing 1**. This particular implementation uses an optimization that switches to insertion sort on small arrays. This speeds up the algorithm because it allows the small data set to fit entirely in cache along with the small amount of code associated with the insertion sort algorithm. See **Listing 2** for a parallel implementation of merge sort.

2.1.3 Applications

Merge sort is useful in applications where the data set will not fit entirely into memory. This allows for the data to be read in from disk and sorted as it is read, thus requiring a very small memory footprint. In addition, when time complexity needs to be guaranteed, merge sort is preferable over quicksort, as quicksort's worst case is $O(n^2)$.

2.2 Quick Sort

2.2.1 Algorithm

2.2.2 Efficiency

2.2.3 Applications

2.3 Shell Sort

2.3.1 Algorithm

2.3.2 Efficiency

2.3.3 Applications

2.4 Comparing and Contrasting

3 Conclusions

A Code Examples

Listing 1: Go implementation of MergeSort

```
1 package main
2
3 var optimize int = 10
4
5 func Merge(arr []int) {
6     if len(arr) < optimize && len(arr) != 1 {
7         InsertionSort(arr)
8     } else if len(arr) > 1 {
9         // Start at the midpoint
10        size := len(arr) / 2
11
12        left := arr[:size]
13        right := arr[size:]
14
15        // Perform sub-merges
16        Merge(left)
17        Merge(right)
18
19        // For holding results
20        data := make([]int, len(arr))
21
22        i := 0
23        for len(left) > 0 && len(right) > 0 {
24            // Decide which list to pull from
25            if left[0] < right[0] {
26                // Put the first value into the results and shrink the array
27                data[i], right = right[0], right[1:]
28            } else {
29                // Same thing for the left
30                data[i], left = left[0], left[1:]
31            }
32            i++ // Next element
```

```

33     }
34
35     // Figure out which list isn't empty
36     var remainder []int
37
38     if len(left) > 0 {
39         remainder = left
40     } else {
41         remainder = right
42     }
43
44     // Empty remaining values
45     for len(remainder) > 0 {
46         data[i], remainder = remainder[0], remainder[1:]
47         i++
48     }
49
50     // Copy result to our answer
51     for i := 0; i < len(arr); i++ {
52         arr[i] = data[i]
53     }
54 }
55 }
56
57 func InsertionSort(arr []int) {
58     for i, j := 1, 1; i < len(arr); i, j = i+1, i+1 {
59         for j > 0 && arr[j] < arr[j-1] {
60             arr[j-1], arr[j] = arr[j], arr[j-1]
61             j--
62         }
63     }
64 }

```

Listing 2: Parallel implementation of MergeSort in Go

```

1 package main
2
3 import "sync"
4
5 var optimize int = 25
6
7 func Merge(arr []int, group *sync.WaitGroup) {
8     if len(arr) < optimize && len(arr) != 1 {
9         InsertionSort(arr)
10    } else if len(arr) > 1 {
11        // Start at the midpoint
12        size := len(arr) / 2
13
14        left := arr[:size]
15        right := arr[size:]
16
17        // Perform sub-merges
18        group := new(sync.WaitGroup)
19        group.Add(2)
20        go Merge(left, group)
21        go Merge(right, group)
22        group.Wait()
23    }

```

```

24 // For holding results
25 data := make([]int, len(arr))
26
27 i := 0
28 for len(left) > 0 && len(right) > 0 {
29     // Decide which list to pull from
30     if left[0] > right[0] {
31         // Put the first value into the results and shrink the array
32         data[i], right = right[0], right[1:]
33     } else {
34         // Same thing for the left
35         data[i], left = left[0], left[1:]
36     }
37     i++ // Next element
38 }
39
40 // Figure out which list isn't empty
41 var remainder []int
42
43 if len(left) > 0 {
44     remainder = left
45 } else {
46     remainder = right
47 }
48
49 // Empty remaining values
50 for len(remainder) > 0 {
51     data[i], remainder = remainder[0], remainder[1:]
52     i++
53 }
54
55 // Copy result to our answer
56 for i := 0; i < len(arr); i++ {
57     arr[i] = data[i]
58 }
59 }
60 group.Done()
61 }
62
63 func InsertionSort(arr []int) {
64     for i, j := 1, 1; i < len(arr); i, j = i+1, i+1 {
65         for j > 0 && arr[j] < arr[j-1] {
66             arr[j-1], arr[j] = arr[j], arr[j-1]
67             j--
68         }
69     }
70 }

```

References

- [1] Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein. *Introduction to algorithms*. MIT Press, Cambridge, Mass, 2nd edition, 2001.