
CS 301

High-Performance Computing

Lab 2 - Performance evaluation of codes

Problem C2: Sorting - Merge Sort.

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1 Introduction

We would use the merge sort strategy to sort this code performance in order to determine its complexity and its specific high performance computing perspective. The article goes on to provide a case study and mathematical concepts.

2 Hardware Details

2.1 Hardware Details for LAB207 PCs

- Architecture: x86_64
- CPU op-mode(s): 32-bit, 64-bit
- Byte Order: Little Endian
- CPU(s): 6
- On-line CPU(s) list: 0-5
- Thread(s) per core: 1
- Core(s) per socket: 6
- Socket(s): 1
- NUMA node(s): 1
- Vendor ID: GenuineIntel
- CPU family: 6
- Model: 155
- Model name: Intel(R) Core(TM) i5-8500 CPU @ 3.00GHz
- Stepping: 10
- CPU MHz: 799.992
- CPU max MHz: 4100.0000
- CPU min MHz: 800.0000
- BogomIPS: 6000.00
- Virtualization: VT-x
- L1d cache: 192KB
- L1i cache: 192KB
- L2 cache: 1.5MB
- L3 cache: 9MB
- NUMA node0 CPU(s): 0-5

2.2 Hardware Details for HPC Cluster (Node gics1)

- Architecture: x86_64
- CPU op-mode(s): 32-bit, 64-bit
- Byte Order: Little Endian
- CPU(s): 24
- On-line CPU(s) list: 0-23
- Thread(s) per core: 2
- Core(s) per socket: 6
- Socket(s): 2
- NUMA node(s): 2
- Vendor ID: GenuineIntel
- CPU family: 6
- Model: 63
- Model name: Intel(R) Xeon(R) CPU E5-2620 v3 @ 2.40GHz
- Stepping: 2
- CPU MHz: 2642.4378
- BogoMIPS: 4804.69
- Virtualization: VT-x
- L1d cache: 32K
- L1i cache: 32K
- L2 cache: 256K
- L3 cache: 15360K
- NUMA node0 CPU(s): 0-5,12-17
- NUMA node1 CPU(s): 6-11,18-23

3 Problem C2

3.1 Brief description with its algorithmic approach

In this work, the performance code is analyzed using the merge sort approach. The objective is to analyze its efficiency and temporal complexity on platforms for high-performance computing (HPC). When it comes to parallel computing, merge sort offers a methodical way to comprehend the behavior and scalability of the code.

1. **Divide:** If the array has one or zero elements, it is already sorted. Otherwise, divide the array into two halves.
2. **Conquer:** Recursively apply merge sort to each half of the array.
3. **Merge:** Merge the two sorted halves to produce a single sorted array. This involves comparing elements from each half and combining them in sorted order.

3.2 The complexity of the algorithm (serial)

To implement the merge sort method, two sorted arrays can be merged using a helper function. Merge sort has a $O(N \log N)$ time complexity, where N is the array's element count.

3.3 Profiling using HPC Cluster (with gprof)

The screenshots of profiling using the HPC Cluster are given below

```
[202101522@gics0 ~]$ gcc -pg serial.c -o output1
[202101522@gics0 ~]$ ./output1 100000000 0
Sorting, Merge-Sort, 100000000, 0, 37, 113223422, 35, 878622910
[202101522@gics0 ~]$ gprof output1 gmon.out > gp.txt
[202101522@gics0 ~]$ cat gp.txt
Flat profile:

Each sample counts as 0.01 seconds.
 %   cumulative   self           self       total
time  seconds    seconds   calls   s/call   s/call  name
 94.90      25.34      25.34 999999999    0.00    0.00  merge
  3.12      26.17        0.83      1      0.83    26.17  mergeSort
  2.16      26.75        0.58             0.02    26.75  main
  0.11      26.78        0.03      2      0.02    0.02  diff

 %
time      the percentage of the total running time of the
          program used by this function.

cumulative a running sum of the number of seconds accounted
seconds    for by this function and those listed above it.

self       the number of seconds accounted for by this
seconds    function alone.  This is the major sort for this
          listing.

calls      the number of times this function was invoked, if
          this function is profiled, else blank.

self       the average number of milliseconds spent in this
ms/call    function per call, if this function is profiled,
          else blank.

total      the average number of milliseconds spent in this
ms/call    function and its descendants per call, if this
          function is profiled, else blank.

name       the name of the function.  This is the minor sort
          for this listing.  The index shows the location of
          the function in the gprof listing.  If the index is
```

Figure 1: Screenshot of terminal from HPC Cluster

3.4 Graph of Problem Size vs Runtime

3.4.1 Graph of Problem Size vs Runtime for LAB207 PCs

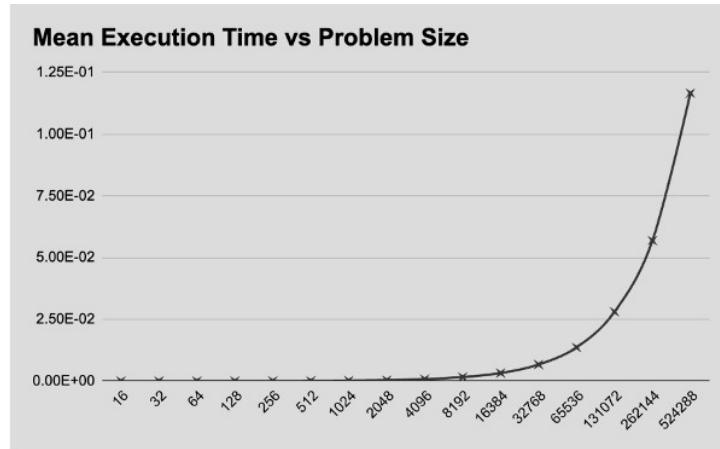


Figure 2: Total mean execution time (Algorithm time) vs Problem size plot for **problem size 10^6** (Hardware: LAB207 PC, Problem: MERGE_SORT).

3.4.2 Graph of Problem Size vs Runtime for HPC Cluster

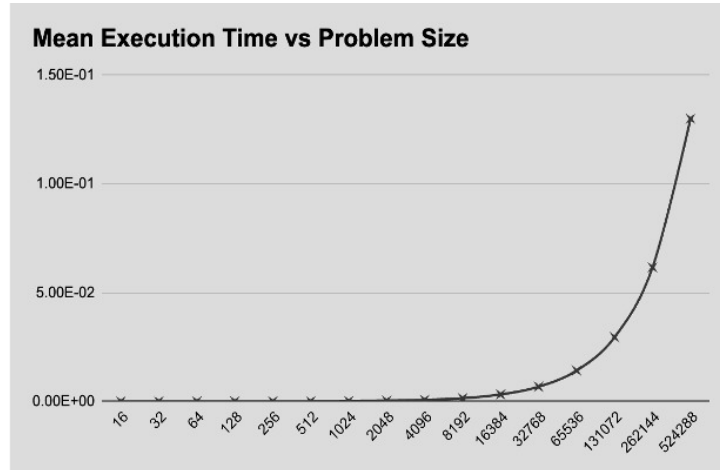


Figure 3: Total mean execution time (Algorithm time) vs Problem size plot for **problem size 10^6** (Hardware: HPC Cluster, Problem: MERGE_SORT).

4 Conclusions

- The length of time required to perform Merge Sort rises exponentially with the complexity of the issue for both the LAB PC and the cluster systems.
- There is a trade-off between the size of the issue and the amount of time required to execute the algorithm; for smaller problems, the method's time consumption makes up a lower fraction of the overall time; but, as the problem gets larger, the algorithm's contribution to the total time grows.