Data Structure HW7 Report

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Environment:

* CPU Speed : Base Speed 3.00 GHz, 6 Core, 12 Thread, Max. Boost ClockUp to 4.0GHz
* Memory : 24.0 GB, SODIMM 3200MHz
* Operating System : Windows 10, Version 22H2
* Compiler : GCC (GNU Compiler Collection) (Rev10, Built by MSYS2 project) 12.2.0

**Insertion Sort**   
(times measured in seconds)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Data Size** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **Avg.** | **比例** |
| 100 | 0.000011 | 0.000014 | 0.000015 | 0.000014 | 0.000011 | 0.000011 | 0.000012 | 0.000012 | 0.000015 | 0.000013 | 0.0000128 | 17.25 |
| 500 | 0.000208 | 0.000225 | 0.000212 | 0.00022 | 0.000208 | 0.00021 | 0.000273 | 0.000239 | 0.000204 | 0.000209 | 0.0002208 | 3.8233696 |
| 1,000 | 0.000762 | 0.001212 | 0.000773 | 0.000764 | 0.000758 | 0.000757 | 0.000771 | 0.001088 | 0.000776 | 0.000781 | 0.0008442 | 21.739161 |
| 5,000 | 0.017921 | 0.017941 | 0.018404 | 0.018024 | 0.017985 | 0.018321 | 0.021045 | 0.017947 | 0.018008 | 0.017926 | 0.0183522 | 3.9426935 |
| 10,000 | 0.073084 | 0.07095 | 0.072208 | 0.071602 | 0.071063 | 0.072931 | 0.073906 | 0.071147 | 0.071743 | 0.074937 | 0.0723571 | 25.088062 |
| 50,000 | 1.810823 | 1.841141 | 1.860447 | 1.831847 | 1.813122 | 1.768417 | 1.892514 | 1.797681 | 1.766055 | 1.770947 | 1.8152994 | 3.953445 |
| 100,000 | 7.340925 | 7.096091 | 7.127624 | 7.120893 | 7.14197 | 7.206478 | 7.152979 | 7.269409 | 7.136992 | 7.173503 | 7.1766864 | 27.001828 |
| 500,000 | 203.80031 | 200.19266 | 194.79836 | 191.48429 | 192.51721 | 192.62732 | 191.84613 | 188.69487 | 190.51499 | 191.3604 | 193.78365 |  |
| 1,000,000 | 786.129252 (TLE) | TLE | TLE | TLE | TLE | TLE | TLE | TLE | TLE | TLE | #DIV/0! |  |
| 5,000,000 | TLE | TLE | TLE | TLE | TLE | TLE | TLE | TLE | TLE | TLE | #DIV/0! |  |

**Merge Sort**(times measured in seconds)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Data Size** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **Avg.** | **比例** |
| 100 | 0.000038 | 0.000047 | 0.000042 | 0.000041 | 0.000056 | 0.000057 | 0.000024 | 0.000037 | 0.000049 | 0.00004 | **0.0000431** | 0.00004361 |
| 500 | 0.000159 | 0.000181 | 0.000171 | 0.000138 | 0.000163 | 0.000175 | 0.000178 | 0.000185 | 0.000168 | 0.000221 | **0.0001739** | 1.884991374 |
| 1,000 | 0.000281 | 0.000311 | 0.000262 | 0.000407 | 0.000308 | 0.00032 | 0.000383 | 0.000262 | 0.000348 | 0.000396 | **0.0003278** | 3.474679683 |
| 5,000 | 0.001276 | 0.001235 | 0.001154 | 0.001114 | 0.001122 | 0.001067 | 0.001074 | 0.001137 | 0.001117 | 0.001094 | **0.001139** | 2.048902546 |
| 10,000 | 0.002467 | 0.002383 | 0.002343 | 0.002378 | 0.002379 | 0.002245 | 0.002345 | 0.002209 | 0.002336 | 0.002252 | **0.0023337** | 5.721386639 |
| 50,000 | 0.012922 | 0.013079 | 0.014637 | 0.014487 | 0.012357 | 0.014334 | 0.013011 | 0.013456 | 0.012177 | 0.01306 | **0.013352** | 1.929239065 |
| 100,000 | 0.026729 | 0.025808 | 0.025926 | 0.025821 | 0.026427 | 0.025369 | 0.025465 | 0.025289 | 0.025123 | 0.025635 | **0.0257592** | 5.653312215 |
| 500,000 | 0.140942 | 0.153884 | 0.138153 | 0.139711 | 0.151455 | 0.148266 | 0.141065 | 0.142667 | 0.146692 | 0.153413 | **0.1456248** | 2.041803319 |
| 1,000,000 | 0.292096 | 0.314748 | 0.287696 | 0.297352 | 0.293913 | 0.303903 | 0.299413 | 0.29467 | 0.293862 | 0.295719 | **0.2973372** | 5.625959685 |
| 5,000,000 | 1.680714 | 1.684642 | 1.676799 | 1.627135 | 1.665881 | 1.790005 | 1.753453 | 1.592149 | 1.593247 | 1.664046 | **1.6728071** |  |

**Radix Sort**(times measured in seconds)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Data Size** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **Avg.** | **比例** |
| 100 | 0.000003 | 0.000003 | 0.000003 | 0.000003 | 0.000003 | 0.000003 | 0.000003 | 0.000003 | 0.000004 | 0.000003 | 0.0000031 | 11.06451613 |
| 500 | 0.000025 | 0.000051 | 0.000033 | 0.000036 | 0.000045 | 0.000051 | 0.000024 | 0.000024 | 0.000029 | 0.000025 | 0.0000343 | 1.778425656 |
| 1,000 | 0.000064 | 0.000059 | 0.000059 | 0.000065 | 0.000059 | 0.000059 | 0.000059 | 0.000063 | 0.000063 | 0.00006 | 0.000061 | 5.708196721 |
| 5,000 | 0.000396 | 0.000573 | 0.000312 | 0.000318 | 0.00031 | 0.000309 | 0.000317 | 0.000313 | 0.000325 | 0.000309 | 0.0003482 | 2.302412407 |
| 10,000 | 0.000785 | 0.000876 | 0.000769 | 0.000783 | 0.000771 | 0.000796 | 0.000915 | 0.000776 | 0.000775 | 0.000771 | 0.0008017 | 5.059249096 |
| 50,000 | 0.004107 | 0.00402 | 0.004044 | 0.004049 | 0.004023 | 0.004049 | 0.004028 | 0.0041 | 0.004059 | 0.004081 | 0.004056 | 2.375986193 |
| 100,000 | 0.00978 | 0.009753 | 0.009596 | 0.009558 | 0.009544 | 0.009654 | 0.00975 | 0.009578 | 0.009595 | 0.009562 | 0.009637 | 5.330486666 |
| 500,000 | 0.051593 | 0.051582 | 0.051191 | 0.052343 | 0.050275 | 0.05227 | 0.051415 | 0.051984 | 0.050774 | 0.050272 | 0.0513699 | 2.161374657 |
| 1,000,000 | 0.10895 | 0.111359 | 0.108475 | 0.109894 | 0.108647 | 0.110009 | 0.109349 | 0.12387 | 0.107604 | 0.112139 | 0.1110296 | 5.888619791 |
| 5,000,000 | 0.640592 | 0.640821 | 0.643266 | 0.643198 | 0.653758 | 0.65357 | 0.649138 | 0.717994 | 0.64463 | 0.651144 | 0.6538111 |  |

**C qsort()**(times measured in seconds)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Data Size** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **Avg.** | **比例** |
| 100 | 0.000014 | 0.000004 | 0.000007 | 0.000006 | 0.000007 | 0.000005 | 0.000004 | 0.000005 | 0.000006 | 0.000004 | **0.0000062** | 6.1612903 |
| 500 | 0.000046 | 0.000036 | 0.000057 | 0.000035 | 0.000034 | 0.000029 | 0.000034 | 0.000038 | 0.000033 | 0.00004 | **0.0000382** | 1.9162304 |
| 1,000 | 0.000088 | 0.000066 | 0.000077 | 0.000072 | 0.000075 | 0.000064 | 0.000071 | 0.000068 | 0.000073 | 0.000078 | **0.0000732** | 5.3497268 |
| 5,000 | 0.000392 | 0.00044 | 0.000379 | 0.000376 | 0.000396 | 0.000393 | 0.000374 | 0.000373 | 0.000365 | 0.000428 | **0.0003916** | 2.1149132 |
| 10,000 | 0.000795 | 0.000862 | 0.000815 | 0.000987 | 0.000777 | 0.000786 | 0.00083 | 0.000789 | 0.00085 | 0.000791 | **0.0008282** | 5.9226032 |
| 50,000 | 0.00466 | 0.00466 | 0.004666 | 0.005143 | 0.004706 | 0.004646 | 0.004673 | 0.004995 | 0.006216 | 0.004686 | **0.0049051** | 2.0260137 |
| 100,000 | 0.009923 | 0.010043 | 0.010121 | 0.009847 | 0.01003 | 0.009763 | 0.010002 | 0.009891 | 0.009802 | 0.009956 | **0.0099378** | 5.7384632 |
| 500,000 | 0.055544 | 0.055156 | 0.055772 | 0.055722 | 0.064277 | 0.056613 | 0.056842 | 0.055726 | 0.055364 | 0.059261 | **0.0570277** | 2.046893 |
| 1,000,000 | 0.116375 | 0.117849 | 0.117239 | 0.115771 | 0.116674 | 0.118314 | 0.116098 | 0.117128 | 0.116159 | 0.115689 | **0.1167296** | 5.7251922 |
| 5,000,000 | 0.66471 | 0.66101 | 0.656378 | 0.668747 | 0.661812 | 0.64349 | 0.672253 | 0.697968 | 0.684761 | 0.671865 | **0.6682994** |  |

**C++ Sort()**(times measured in seconds)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Data Size** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **Avg.** | **比例** |
| 100 | 0.000007 | 0.000006 | 0.000006 | 0.000013 | 0.000005 | 0.000007 | 0.000006 | 0.000007 | 0.000006 | 0.000007 | **0.000007** | 6.2857143 |
| 500 | 0.000041 | 0.000033 | 0.000079 | 0.000041 | 0.000051 | 0.000038 | 0.00004 | 0.000041 | 0.000038 | 0.000038 | **0.000044** | 1.7477273 |
| 1,000 | 0.00007 | 0.000086 | 0.000073 | 0.000082 | 0.000074 | 0.00007 | 0.000083 | 0.000082 | 0.000074 | 0.000075 | **0.0000769** | 5.7022107 |
| 5,000 | 0.000438 | 0.000442 | 0.000434 | 0.000433 | 0.000431 | 0.000429 | 0.000434 | 0.000435 | 0.000462 | 0.000447 | **0.0004385** | 2.3384265 |
| 10,000 | 0.000942 | 0.000946 | 0.000955 | 0.000939 | 0.001127 | 0.000948 | 0.000954 | 0.000977 | 0.000944 | 0.001522 | **0.0010254** | 5.8439633 |
| 50,000 | 0.006497 | 0.005421 | 0.005307 | 0.005758 | 0.005771 | 0.007636 | 0.005315 | 0.007177 | 0.005284 | 0.005758 | **0.0059924** | 1.9245878 |
| 100,000 | 0.012769 | 0.011065 | 0.011103 | 0.011461 | 0.011604 | 0.011117 | 0.011592 | 0.011243 | 0.011599 | 0.011776 | **0.0115329** | 5.8578502 |
| 500,000 | 0.064128 | 0.064076 | 0.065007 | 0.065763 | 0.07713 | 0.06347 | 0.063922 | 0.064978 | 0.070945 | 0.076161 | **0.067558** | 1.9769709 |
| 1,000,000 | 0.133298 | 0.134097 | 0.133821 | 0.133589 | 0.132818 | 0.133799 | 0.132521 | 0.133632 | 0.134884 | 0.133143 | **0.1335602** | 5.7078306 |
| 5,000,000 | 0.756803 | 0.802682 | 0.752354 | 0.754644 | 0.761051 | 0.782518 | 0.740307 | 0.782941 | 0.753709 | 0.736381 | **0.762339** |  |

From the above data, it is evident that Selection Sort is the least efficient sorting algorithm. As the data size doubles, the time taken to complete the sorting process increases fourfold. Moreover, when the data size increases by a factor of five, the time taken rises to over 20 times the original duration. Among the algorithms analysed, the radix sort function emerges as the best performer, taking an average of 0.65 seconds to sort five million numbers, followed by qsort() by only left behind with 0.01 seconds. Interestingly, all other sorting algorithms, except for Selection Sort, demonstrate efficiency close to linearity. This implies that as the data size doubles, the time taken also approximately doubles.

An intriguing observation I made is the significant impact of CPU clock speed on sorting efficiency. During an experiment where I ran the sorting algorithms on my laptop with an underclocked CPU, the time taken for completion was consistently twice as long as under normal conditions.