Numbers are set to 1 (I am still randomly generating them, taking a mod, then adding the lower bound, see lines 50-52). Note: This was done on my local machine, not the Knuth server. The row in each table for 20 threads is there for testing whether or not the program would keep its efficiency from 2 threads to 20 threads with multiplying the work by 10 as well. Column 1000 with 16 threads is N/A because 16 does not divide 1000.

Busy-Waiting **IS** strongly scalable because the efficiency increases as we go across the chart below. The rest **ARE NOT** scalable at all.

**Tables for Busy-Waiting**

Table 3.5: Times (seconds)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 0.000152 | 0.000267 | 0.000269 | 0.000401 | 0.000649 | 0.003265 | 0.019778 | 0.199848 |
| 2 | 0.000209 | 0.000207 | 0.000299 | 0.000382 | 0.000563 | 0.002953 | 0.022120 | 0.207446 |
| 4 | 0.000404 | 0.000268 | 0.002050 | 0.000380 | 0.000554 | 0.002560 | 0.022063 | 0.205882 |
| 8 | 0.000469 | 0.000539 | 0.000577 | 0.000706 | 0.000547 | 0.002509 | 0.022741 | 0.194383 |
| 16 | N/A | 0.000851 | 0.000798 | 0.000894 | 0.001075 | 0.002481 | 0.024626 | 0.226038 |
| 20 | 0.000842 | 0.001027 | 0.000864 | 0.001084 | 0.001115 | 0.002424 | 0.025193 | 0.229891 |

Table 3.6: Speedup

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| 2 | 0.72727 | 1.28986 | 0.89967 | 1.04974 | 1.15275 | 1.10566 | 0.89412 | 0.96337 |
| 4 | 0.37624 | 0.99627 | 0.13122 | 1.05526 | 1.17148 | 1.27539 | 0.89643 | 0.97069 |
| 8 | 0.32409 | 0.49536 | 0.46620 | 0.56799 | 1.18647 | 1.30132 | 0.86971 | 1.02811 |
| 16 | N/A | 0.31375 | 0.33709 | 0.44855 | 0.60372 | 1.31600 | 0.80313 | 0.88413 |
| 20 | 0.18052 | 0.25998 | 0.31134 | 0.36993 | 0.58206 | 1.34695 | 0.78506 | 0.86932 |

Table 3.7: Efficiency

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 |
| 2 | 0.363636 | 0.644928 | 0.449833 | 0.524869 | 0.576377 | 0.552828 | 0.447061 | 0.481687 |
| 4 | 0.094059 | 0.249067 | 0.032805 | 0.263816 | 0.292870 | 0.318848 | 0.224108 | 0.242673 |
| 8 | 0.040512 | 0.061920 | 0.058276 | 0.070999 | 0.148309 | 0.162664 | 0.108713 | 0.128514 |
| 16 | N/A | 0.019609 | 0.021068 | 0.028034 | 0.037733 | 0.082250 | 0.050196 | 0.055258 |
| 20 | 0.009026 | 0.012999 | 0.015567 | 0.018496 | 0.029103 | 0.067347 | 0.039253 | 0.043466 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sums** | **Order of Matrix** | | | | | | | |
| Thread Count | 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 2 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 4 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 8 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 16 | N/A | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 20 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |

**Tables for Semaphore**

Table 3.5: Times (seconds)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 0.000159 | 0.000241 | 0.000232 | 0.000479 | 0.000708 | 0.003384 | 0.030304 | 0.297025 |
| 2 | 0.000138 | 0.000425 | 0.000295 | 0.000907 | 0.001507 | 0.007610 | 0.075718 | 0.883223 |
| 4 | 0.000323 | 0.000276 | 0.000418 | 0.000693 | 0.000926 | 0.007934 | 0.087466 | 0.887276 |
| 8 | 0.000582 | 0.000385 | 0.000438 | 0.000711 | 0.003614 | 0.008553 | 0.114297 | 1.022534 |
| 16 | 0.000687 | 0.000863 | 0.000910 | 0.000760 | 0.001085 | 0.013658 | 0.138410 | 1.278348 |
| 20 | 0.000750 | 0.001501 | 0.000920 | 0.001261 | 0.001384 | 0.014448 | 0.129305 | 1.187081 |

Table 3.6: Speedup

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| 2 | 1.15217 | 0.56706 | 0.78644 | 0.52811 | 0.46981 | 0.44468 | 0.40022 | 0.33630 |
| 4 | 0.49226 | 0.87319 | 0.55502 | 0.69120 | 0.76458 | 0.42652 | 0.34647 | 0.33476 |
| 8 | 0.27320 | 0.62597 | 0.52968 | 0.67370 | 0.19590 | 0.39565 | 0.26513 | 0.29048 |
| 16 | N/A | 0.27926 | 0.25495 | 0.63026 | 0.65253 | 0.24777 | 0.21894 | 0.23235 |
| 20 | 0.21200 | 0.16056 | 0.25217 | 0.37986 | 0.51156 | 0.23422 | 0.23436 | 0.25021 |

Table 3.7: Efficiency

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 |
| 2 | 0.576087 | 0.283529 | 0.393220 | 0.264057 | 0.234904 | 0.222339 | 0.200111 | 0.168148 |
| 4 | 0.123065 | 0.218297 | 0.138756 | 0.172799 | 0.191145 | 0.106630 | 0.086617 | 0.083690 |
| 8 | 0.034149 | 0.078247 | 0.066210 | 0.084212 | 0.024488 | 0.049456 | 0.033142 | 0.036310 |
| 16 | N/A | 0.017454 | 0.015934 | 0.039391 | 0.040783 | 0.015485 | 0.013684 | 0.014522 |
| 20 | 0.010600 | 0.008028 | 0.012609 | 0.018993 | 0.025578 | 0.011711 | 0.011718 | 0.012511 |
| **Sums** | **Order of Matrix** | | | | | | | |
| Thread Count | 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 2 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 4 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 8 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 16 | N/A | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 20 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |

**Tables for Mutex**

Table 3.5: Times (seconds)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 0.000154 | 0.000234 | 0.000230 | 0.000424 | 0.000612 | 0.003464 | 0.030581 | 0.299794 |
| 2 | 0.000125 | 0.000152 | 0.001195 | 0.001926 | 0.004239 | 0.032389 | 0.253653 | 2.776409 |
| 4 | 0.000364 | 0.000327 | 0.000562 | 0.001945 | 0.004349 | 0.027553 | 0.272127 | 2.837371 |
| 8 | 0.000513 | 0.000688 | 0.000632 | 0.000469 | 0.003888 | 0.029903 | 0.339278 | 3.246509 |
| 16 | 0.000618 | 0.000758 | 0.000717 | 0.002332 | 0.004141 | 0.037671 | 0.464385 | 4.645715 |
| 20 | 0.000889 | 0.000821 | 0.000869 | 0.000814 | 0.003707 | 0.043863 | 0.510565 | 5.071570 |

Table 3.6: Speedup

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| 2 | 1.23200 | 1.53947 | 0.19247 | 0.22015 | 0.14437 | 0.10695 | 0.12056 | 0.10798 |
| 4 | 0.42308 | 0.71560 | 0.40925 | 0.21799 | 0.14072 | 0.12572 | 0.11238 | 0.10566 |
| 8 | 0.30019 | 0.34012 | 0.36392 | 0.90405 | 0.15741 | 0.11584 | 0.09014 | 0.09234 |
| 16 | N/A | 0.30871 | 0.32078 | 0.18182 | 0.14779 | 0.09195 | 0.06585 | 0.06453 |
| 20 | 0.17323 | 0.28502 | 0.26467 | 0.52088 | 0.16509 | 0.07897 | 0.05990 | 0.05911 |

Table 3.7: Efficiency

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 |
| 2 | 0.616000 | 0.769737 | 0.096234 | 0.110073 | 0.072187 | 0.053475 | 0.060281 | 0.053990 |
| 4 | 0.105769 | 0.178899 | 0.102313 | 0.054499 | 0.035181 | 0.031430 | 0.028094 | 0.026415 |
| 8 | 0.037524 | 0.042515 | 0.045491 | 0.113006 | 0.019676 | 0.014480 | 0.011267 | 0.011543 |
| 16 | N/A | 0.019294 | 0.020049 | 0.011364 | 0.009237 | 0.005747 | 0.004116 | 0.004033 |
| 20 | 0.008661 | 0.014251 | 0.013234 | 0.026044 | 0.008255 | 0.003949 | 0.002995 | 0.002956 |
| **Sums** | **Order of Matrix** | | | | | | | |
| Thread Count | 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 2 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 4 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 8 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 16 | N/A | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 20 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |

**Tables for Read-Write**

Table 3.5: Times (seconds)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 0.000239 | 0.000263 | 0.000270 | 0.000487 | 0.000773 | 0.004322 | 0.039271 | 0.385382 |
| 2 | 0.000135 | 0.000194 | 0.000438 | 0.000839 | 0.002018 | 0.012498 | 0.125909 | 1.213322 |
| 4 | 0.000203 | 0.000289 | 0.000319 | 0.001205 | 0.002302 | 0.014781 | 0.159327 | 1.503742 |
| 8 | 0.000463 | 0.000461 | 0.000525 | 0.001166 | 0.002555 | 0.016887 | 0.188307 | 1.872407 |
| 16 | 0.000581 | 0.001119 | 0.000679 | 0.001440 | 0.003106 | 0.019455 | 0.175420 | 1.809285 |
| 20 | 0.000718 | 0.000773 | 0.000801 | 0.000849 | 0.001769 | 0.017766 | 0.172643 | 1.609996 |

Table 3.6: Speedup

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 | 1.00000 |
| 2 | 1.77037 | 1.35567 | 0.61644 | 0.58045 | 0.38305 | 0.34582 | 0.31190 | 0.31763 |
| 4 | 1.17734 | 0.91003 | 0.84639 | 0.40415 | 0.33579 | 0.29240 | 0.24648 | 0.25628 |
| 8 | 0.51620 | 0.57050 | 0.51429 | 0.41767 | 0.30254 | 0.25594 | 0.20855 | 0.20582 |
| 16 | N/A | 0.23503 | 0.39764 | 0.33819 | 0.24887 | 0.22215 | 0.22387 | 0.21300 |
| 20 | 0.33287 | 0.34023 | 0.33708 | 0.57362 | 0.43697 | 0.24327 | 0.22747 | 0.23937 |

Table 3.7: Efficiency

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Thread Count | **Order of Matrix** | | | | | | | |
| 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 1.000000 |
| 2 | 0.885185 | 0.677835 | 0.308219 | 0.290226 | 0.191526 | 0.172908 | 0.155950 | 0.158813 |
| 4 | 0.294335 | 0.227509 | 0.211599 | 0.101037 | 0.083949 | 0.073101 | 0.061620 | 0.064070 |
| 8 | 0.064525 | 0.071312 | 0.064286 | 0.052208 | 0.037818 | 0.031992 | 0.026068 | 0.025728 |
| 16 | N/A | 0.014689 | 0.024853 | 0.021137 | 0.015555 | 0.013885 | 0.013992 | 0.013313 |
| 20 | 0.016643 | 0.017012 | 0.016854 | 0.028681 | 0.021849 | 0.012164 | 0.011373 | 0.011968 |
| **Sums** | **Order of Matrix** | | | | | | | |
| Thread Count | 1000 | 2000 | 4000 | 8000 | 16,000 | 100,000 | 1 million | 10 million |
| 1 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 2 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 4 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 8 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 16 | N/A | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |
| 20 | 1000 | 2000 | 4000 | 8000 | 16000 | 100000 | 1 million | 10 million |