Andrew Frost CS415 PA4 Report 04/26/2017

### **Overview:**

In this programming assignment matrices were multiplied using sequential and parallel algorithms. The sequential program made us of a simplistic matrix multiplication algorithm that ran in  $O(n^3)$ . Cannon's algorithm was used in the parallel program. In this report the parallel run times and sequential run times are compared. The complete data for this report can be found in data.xlsx. Table 1 shows a sample result of matrix multiplication.

<b>Matrix Multiplication Results</b>							
	Mat A:						
		1	2	3			
		2	3	4			
		3	4	5			
	Mat B:						
		3	2	1			
		4	3	2 3			
		5	4	3			
	Mat C:						
		26	20	14			
		38	29	20			
		50	38	26			

Table 1: an example of multiplying two 3x3 matrices using the sequential algorithm.

Table 1 shows a sample result from multiplying two matrices together using the sequential algorithm. The sequential algorithm will be discussed in depth below.

## **Sequential:**

The sequential algorithm run times are based off of single sample run times. On select tests, multiple time trials were ran and little deviation was found. Based on the low variance found in select sample run times, the data used in this report for sequential run times was not averaged or processed. The sequential algorithm used had a time complexity of  $O(n^3)$  and the run time results reflect this curve. Figure 1 graphs the run times of the sequential algorithm.

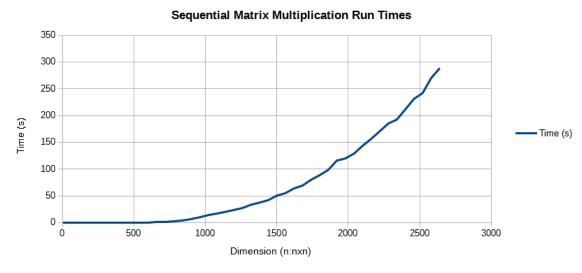


Figure 1: a graph of sequential run times in seconds. As the size of the matrix increases, the run time required increases dramatically.

As seen in the graph in Figure 1, the run time of the sequential algorithm increases dramatically as the matrix dimension size increases. The maximum tested dimension of 2640x2640 neared five minutes in run time. This not only shows the undesirability of an  $O(n^3)$ , but highlights the need for an efficient parallel algorithm. The run times of the sequential algorithm are included in Table 2.

# **Sequential Matrix Multiplication Run Times**

10 3E-06 12 4E-06 15 1E-09 20 2.1E-09 24 3.4E-09 25 7.2E-09 30 3.7E-09 35 9.9E-09 36 0.000100 40 8.1E-09 45 0.000200 48 0.000240 50 0.000200 55 0.000680 60 0.00047 120 0.00280 180 0.010290 240 0.018880 300 0.03587 360 0.066720 420 0.224460 480 0.20485 600 0.360542 600 0.360542 600 0.360542 600 0.360544	Dimension (n:nxn)	Time (s)
12	5	1E-06
15	10	3E-06
20 2.1E-06 24 3.4E-06 25 7.2E-06 30 3.7E-06 35 9.9E-06 36 0.000106 40 8.1E-06 45 0.000206 48 0.000247 50 0.000286 55 0.000686 60 0.000477 120 0.002883 300 0.035879 360 0.066726 420 0.224466 480 0.204856 660 0.752537 720 0.730666 780 2.41056 840 3.80099 900 6.4189 960 9.80506 1020 13.8666 1080 16.7186 1140 19.9146 1200 23.4706 1320 33.3196	12	4E-06
24 3.4E-09 25 7.2E-09 30 3.7E-09 35 9.9E-09 36 0.000109 40 8.1E-09 45 0.000208 48 0.000249 50 0.000208 55 0.000689 60 0.000479 120 0.02888 300 0.035879 360 0.066729 420 0.224468 480 0.204859 540 0.263549 600 0.360549 660 0.752537 720 0.730666 780 2.41059 840 3.8009 900 6.4189 960 9.8050 1020 13.8669 1080 16.7189 1140 19.9149 1200 23.4709 1260 27.1661 1320 33.3199 1380 37.279 1440 41.7461 1500 50.1509 1560 54.8448 1620 63.6477 1680 69.1077 1740 79.9139 1800 18.712 1900 143.309 2040 128.711 2100 143.309 2240 128.711 2100 143.309 2240 128.711 2260 27.1519 2280 184.983 2340 192.441	15	1E-05
25	20	2.1E-05
30 3.7E-08 35 9.9E-08 36 0.000108 40 8.1E-08 45 0.000208 48 0.000248 50 0.000208 55 0.000688 60 0.000478 120 0.00288 180 0.010299 240 0.018888 300 0.035878 360 0.066728 420 0.224468 480 0.204858 660 0.75253 720 0.730666 780 2.41058 840 3.80098 900 6.4188 960 9.8050 1020 13.8668 1080 16.7188 1140 19.9148 1200 23.4708 1260 27.166 1320 33.3198 1380 37.2799 1440 41.746 1500 50.1508 1560 54.8488 1620 63.6477 1680 69.1077 1740 79.9138 1800 88.393 1860 98.305 1920 115.66 1980 119.799 2040 128.717 2100 143.308 2160 156.222 2220 170.518 2280 184.983	24	3.4E-05
35 9.9E-06 36 0.000108 40 8.1E-06 45 0.000208 48 0.000208 50 0.000208 55 0.000688 60 0.000478 120 0.00288 180 0.010298 240 0.01888 300 0.035878 360 0.066722 420 0.224468 480 0.204858 540 0.263544 600 0.360542 660 0.75253 720 0.730666 780 2.41056 840 3.80098 900 6.4188 960 9.80500 1020 13.8668 1080 16.7188 1140 19.9144 1200 23.4708 1260 27.1666 1320 33.3198 1380 37.2799 1440 41.7466 1500 50.1508 1560 54.8488 1620 63.6477 1680 69.107 1740 79.9138 1800 88.393 1860 98.305 1920 115.560 1920 17.519 2040 128.712 2100 143.308 2160 156.226 2220 170.518 2280 184.983	25	7.2E-05
35 9.9E-06 36 0.000108 40 8.1E-06 45 0.000208 48 0.000208 50 0.000208 55 0.000688 60 0.000478 120 0.00288 180 0.010298 240 0.01888 300 0.035878 360 0.066722 420 0.224468 480 0.204858 540 0.263544 600 0.360542 660 0.75253 720 0.730666 780 2.41056 840 3.80098 900 6.4188 960 9.80500 1020 13.8668 1080 16.7188 1140 19.9144 1200 23.4708 1260 27.1666 1320 33.3198 1380 37.2799 1440 41.7466 1500 50.1508 1560 54.8488 1620 63.6477 1680 69.107 1740 79.9138 1800 88.393 1860 98.305 1920 115.560 1920 17.519 2040 128.712 2100 143.308 2160 156.226 2220 170.518 2280 184.983	30	3.7E-05
36 0.000108 40 8.1E-09 45 0.000208 48 0.000247 50 0.000208 55 0.000688 60 0.00047 120 0.002883 180 0.010299 240 0.018888 300 0.035873 360 0.0667722 420 0.224468 480 0.204858 540 0.263544 600 0.360544 660 0.75253 720 0.73066 780 2.41058 840 3.80099 900 6.4188 960 9.80506 1020 13.8668 1080 16.7188 1140 19.9144 1200 23.4702 1260 27.1666 1320 33.3196 1380 37.2796 1440 41.7466 1500 50.1508 1560 54.84488 1620 63.6477 1680 69.1077 1740 79.9138 1800 88.3937 1860 98.3056 1920 115.568 1920 115.568 1920 119.799 2040 128.711 2100 143.308 22160 156.222 2220 170.511 2280 184.983		
40 8.1E-09 45 0.000208 48 0.00024 50 0.000208 55 0.000688 60 0.00047 120 0.00288 180 0.010298 240 0.01888 300 0.03587 360 0.066728 420 0.22446 480 0.22446 600 0.360542 660 0.75253 720 0.73066 780 2.4105 840 3.8009 900 6.418 960 9.8050 1020 13.8668 1080 16.7188 1140 19.9148 1200 23.4702 1260 27.166 1320 33.3196 1380 37.279 1440 41.746 1500 50.1508 1560 54.848 1620 63.647 1680 69.107 1740 79.9138 1800 88.393 1860 98.305 1920 115.508 1980 119.799 2040 128.712 2100 143.308 2160 156.222 2220 170.518 2280 184.983		0.000108
45 0.000208 48 0.00024 50 0.000208 55 0.00068 60 0.00047 120 0.00288 180 0.010299 240 0.01888 300 0.03587 360 0.066728 420 0.22446 480 0.20485 540 0.263544 600 0.360542 660 0.75253 720 0.73066 780 2.4105 840 3.8009 900 6.418 960 9.8050 1020 13.8668 1080 16.718 1140 19.9148 1200 23.4706 1320 33.319 1380 37.279 1440 41.746 1500 50.1508 1560 54.8488 1620 63.647 1680 69.107 1740 79.9138 1800 88.393 1860 98.305 1920 115.68 1980 119.79 2040 128.712 2100 143.308 22160 156.22 2220 170.518 2280 184.98	40	
48		
50  0.000208 55  0.000688 60  0.000478 120  0.00288 180  0.010299 240  0.018888 300  0.035878 360  0.066728 420  0.224468 480  0.204858 540  0.263548 600  0.360548 660  0.75253 720  0.730666 780  2.41058 840  3.80098 900  6.4188 960  9.8050 1020  13.8668 1080  16.7188 1140  19.9148 1200  23.4708 1260  27.166 1320  33.3199 1380  37.2799 1440  41.746 1500  50.1508 1560  54.8488 1620  63.647 1680  69.107 1740  79.9138 1800  88.393 1860  98.305 1920  115.68 1980  199.74 2100  143.308 22160  156.222 2220  170.518 2280  184.983 2340  192.4448 2400  211.718 2460  231.256		
55 0.000688 60 0.000478 120 0.002883 180 0.010298 240 0.018888 300 0.035879 360 0.066728 420 0.224468 480 0.204858 540 0.263544 600 0.360542 660 0.752533 720 0.73066 780 2.41059 840 3.80098 900 6.4188 960 9.80500 1020 13.8668 1080 16.7188 1140 19.9149 1200 23.4709 1260 27.1667 1320 33.3198 1380 37.279 1440 41.746 1500 50.1508 1560 54.8488 1620 63.6477 1680 69.107 1740 79.9138 1800 88.393 1860 98.305 1920 115.66 1980 119.799 2040 128.712 2100 143.308 2160 156.226 2220 170.518 2280 184.988		
60 0.000478 120 0.002883 180 0.010298 240 0.018888 300 0.035873 360 0.066722 420 0.224466 480 0.204856 540 0.263544 660 0.75253 720 0.73066 780 2.41056 840 3.80099 900 6.4188 960 9.80500 1020 13.8666 1080 16.7186 1140 19.9144 1200 23.4702 1260 27.1666 1320 33.3196 1380 37.2790 1440 41.746 1500 50.1500 1560 54.8448 1620 63.6477 1680 69.1077 1740 79.9138 1800 88.3937 1860 98.3056 1920 115.566 1920 115.62 2220 170.511 2280 184.983 2340 192.444		
120 0.00288: 180 0.010298 240 0.01888 300 0.035879 360 0.066729 420 0.22446 480 0.204856 540 0.263546 660 0.752537 720 0.73066 780 2.41056 840 3.80099 900 6.4188 960 9.80500 1020 13.8666 1080 16.7188 11140 19.9148 1200 23.4702 1260 27.166 1320 33.3190 1380 37.2790 1440 41.7461 1500 50.1508 1560 54.8488 1620 63.6477 1680 69.1077 1740 79.9138 1800 88.3937 1860 98.3057 1920 115.568 1980 119.799 2040 128.711 2100 143.300 22160 156.222 2220 170.511 2280 184.983 2340 192.448		
180		
240 0.018888 300 0.035879 360 0.066728 420 0.224468 480 0.204859 540 0.263544 600 0.360542 660 0.752537 720 0.730666 780 2.41059 840 3.80099 900 6.4188 960 9.80500 1020 13.8669 1080 16.7189 1140 19.9149 1200 23.4707 1260 27.1667 1320 33.3199 1380 37.2794 1440 41.7467 1500 50.1508 1560 54.8488 1620 63.6477 1680 69.1077 1740 79.9138 1800 88.3937 1860 98.3057 1920 115.668 1980 119.799 2040 128.711 2100 143.309 2160 156.224 2220 170.518 2280 184.983 2340 192.4448 2400 211.719 2460 231.257		
300 0.035878 360 0.066728 420 0.224468 480 0.204486 540 0.263544 600 0.360544 660 0.75253 720 0.730666 780 2.41056 840 3.80098 900 6.4188 960 9.8050 1020 13.8668 1080 16.7188 1140 19.9144 1200 23.4706 1320 33.3198 1380 37.2799 1440 41.746 1500 50.1508 1560 54.8488 1620 63.647 1680 69.107 1740 79.9138 1800 88.393 1860 98.305 1920 115.66 1980 1997 2040 128.712 2100 143.308 2160 156.224 2220 170.518 2280 184.983 2340 192.4448 2400 211.748		
360 0.066728 420 0.224468 480 0.204858 540 0.263548 600 0.360553 720 0.73066 780 2.41058 840 3.80098 900 6.4188 960 9.8050 1020 13.8668 1140 19.9148 1200 23.4708 1260 27.1667 1320 33.3198 1380 37.279 1440 41.746 1500 50.1508 1660 54.8488 1620 63.647 1680 69.107 1740 79.9138 1800 88.393 1860 98.393 1860 98.393 1860 98.305 1920 115.66 1980 119.798 2040 128.712 2100 143.308 22160 156.226 2220 170.518 2280 184.983 2340 192.448		
420 0.224468 480 0.204858 540 0.263544 600 0.360542 660 0.75253 720 0.73066 780 2.41059 840 3.80098 900 6.4188 960 9.80500 1020 13.8668 1080 16.7188 1140 19.9149 1200 23.4709 1260 27.1669 1320 33.3199 1380 37.279 1440 41.746 1500 50.1500 1560 54.8488 1620 63.647 1680 69.107 1740 79.9138 1800 88.393 1860 98.305 1920 115.66 1980 119.799 2040 128.712 2100 143.308 2160 156.226 2220 170.518 2280 184.983 2340 192.444 2400 211.719 2460 231.255		
480 0.204858 540 0.263544 600 0.360542 660 0.75253 720 0.730664 780 2.41053 840 3.80099 900 6.4183 960 9.80500 1020 13.8663 1080 16.7183 1140 19.9144 1200 23.4703 1260 27.1663 1320 33.3199 1380 37.2799 1440 41.7466 1500 50.1503 1560 54.8483 1620 63.647 1680 69.107 1740 79.9133 1800 88.393 1860 98.305 1920 115.69 1920 115.69 1980 119.799 2040 128.712 2100 143.303 2160 156.224 2220 170.518 2280 184.983 2340 192.444 2400 211.715 2460 231.255		
540 0.263544 600 0.36054; 660 0.75253; 720 0.73066; 780 2.4105; 840 3.8009; 900 6.418; 960 9.8050; 1020 13.866; 1080 16.718; 1140 19.914; 1200 23.470; 1260 27.166; 1320 33.319; 1380 37.279; 1440 41.746; 1500 50.150; 1560 54.848; 1620 63.647; 1680 69.107; 1740 79.913; 1800 88.393; 1860 98.305; 1920 115.66; 1980 119.79; 2040 128.71; 2100 143.30; 2160 156.22; 2220 170.51; 2280 184.98; 2340 192.44; 2400 211.71; 2460 231.25;		
600 0.360542 660 0.75253 720 0.73066 780 2.41053 840 3.80099 900 6.4184 960 9.80504 1020 13.8663 1080 16.7184 1140 19.9144 1200 23.4705 1320 33.3199 1380 37.2794 1440 41.746 1500 50.1503 1560 54.8448 1620 63.647 1680 69.107 1740 79.9133 1800 88.393 1860 98.305 1920 115.63 1980 119.794 2040 128.712 2100 143.303 2160 156.224 2220 170.515 2280 184.983 2340 192.444 2400 211.715 2460 231.255		
660 0.75253 720 0.73066 780 2.41055 840 3.80099 900 6.4181 960 9.8050 1020 13.8666 1080 16.7186 1140 19.9144 1200 23.4706 1320 33.3196 1380 37.2794 1440 41.746 1500 50.1506 1560 54.8486 1620 63.647 1680 69.107 1740 79.913 1800 88.393 1860 98.305 1920 115.66 1980 119.796 2040 128.712 2100 143.306 2160 156.22 2220 170.515 2280 184.983 2340 192.444 2400 211.715 2460 231.256		
720 0.730664 780 2.41056 840 3.80099 900 6.4186 960 9.80556 1020 13.8666 1080 16.7186 1140 19.9146 1200 23.4706 1260 27.1666 1320 33.3196 1380 37.2796 1440 41.746 1500 50.1506 1560 54.8486 1620 63.6477 1680 69.1077 1740 79.9137 1800 88.3937 1860 98.305 1920 115.66 1980 119.796 2040 128.712 2100 143.306 2160 156.222 2220 170.516 2280 184.986 2340 192.446 2400 211.716 2460 231.256		
780 2.41058 840 3.80098 900 6.4188 960 9.80504 1020 13.8668 1080 16.7188 1140 19.9148 1200 23.4708 1260 27.1666 1320 33.3198 1380 37.2794 1440 41.746 1500 50.1508 1660 54.8488 1620 63.647 1680 69.107 1740 79.9138 1800 88.393 1860 98.393 1860 98.395 1920 115.66 1980 119.798 2040 128.712 2100 143.308 2160 156.224 2220 170.518 2280 184.988 2340 192.4488 2400 211.718 2460 231.255		
840 3.80099 900 6.4184 960 9.80500 1020 13.8669 1080 16.7184 1140 19.9144 1200 23.4709 1260 27.1669 1320 33.3199 1380 37.2799 1440 41.7469 1500 50.1500 1560 54.8489 1620 63.6477 1680 69.1077 1740 79.9139 1800 88.3939 1860 98.3059 1920 115.69 1980 119.799 2040 128.712 2100 143.309 2160 156.222 2220 170.519 2280 184.983 2340 192.441 2400 211.719 2460 231.259		
900 6.418 960 9.8050 1020 13.866 1080 16.718 1140 19.914 1200 23.470 1260 27.166 1320 33.319 1380 37.279 1440 41.746 1500 50.150 1560 54.848 1620 63.647 1680 69.107 1740 79.913 1800 88.393 1860 98.305 1920 115.66 1920 115.62 2040 128.71 2100 143.30 2160 156.22 2220 170.518 2280 184.98 2340 192.418		2.41055
960 9.80504 1020 13.8668 1080 16.7188 1140 19.9148 1200 23.4770 1260 27.166 1320 33.3199 1380 37.2794 1440 41.746 1500 50.1508 1560 54.8448 1620 63.647 1680 69.107 1740 79.9138 1800 88.393 1860 98.305 1920 115.66 1980 119.79 2040 128.712 2100 143.308 2160 156.224 2220 170.518 2280 184.983 2340 192.4484 2400 211.718 2460 231.25		3.80099
1020 13.8668 1080 16.7188 1140 19.9148 1200 23.4706 1260 27.166 1320 33.3199 1380 37.279 1440 41.746 1500 50.1508 1560 54.8448 1620 63.647 1680 69.107 1740 79.913 1800 88.393 1860 98.305 1920 115.66 1980 119.79 2040 128.71 2100 143.308 2160 156.22 2220 170.518 2280 184.983 2340 192.448 2400 211.718 2460 231.25	900	6.4185
1080 16.7186 1140 19.9144 1200 23.4706 1260 27.1666 1320 33.319 1380 37.279 1440 41.746 1500 50.1506 1560 54.8486 1620 63.647 1680 69.107 1740 79.9136 1800 88.393 1860 98.305 1920 115.66 1980 119.796 2040 128.712 2100 143.306 2160 156.22 2220 170.516 2280 184.986 2340 192.446 2400 211.716 2460 231.25		9.80504
1140 19.9148 1200 23.4708 1260 27.166 1320 33.3198 1380 37.2794 1440 41.746 1500 50.1508 1660 54.8488 1620 63.647 1680 69.107 1740 79.9138 1800 88.393 1860 98.393 1860 98.305 1920 115.68 1980 119.798 2040 128.712 2100 143.308 2160 156.22 2220 170.518 2280 184.988 2340 192.448 2400 211.718 2460 231.25		13.8669
1200 23.4703 1260 27.1663 1320 33.3194 1380 37.2794 1440 41.746 1500 50.1503 1560 54.8483 1620 63.6477 1680 69.1077 1740 79.9133 1800 88.3937 1860 98.3937 1860 98.3937 1860 119.793 1920 115.66 1980 119.793 2040 128.713 2100 143.303 2160 156.224 2220 170.513 2280 184.943 2340 192.441 2400 211.713 2460 231.255	1080	16.7188
1260 27.166 1320 33.3196 1380 37.279 1440 41.746 1500 50.1506 1560 54.8486 1620 63.647 1680 69.107 1740 79.9136 1800 88.393 1860 98.305 1920 115.66 1980 119.796 2040 128.712 2100 143.306 2160 156.226 2220 170.516 2280 184.983 2340 192.471 2460 231.25 2520 241.846		19.9145
1320 33.3196 1380 37.2794 1440 41.746 1500 50.1503 1560 54.8484 1620 63.6477 1680 69.1077 1740 79.9133 1800 88.3937 1860 98.3057 1920 115.56 1980 119.799 2040 128.712 2100 143.303 2160 156.224 2220 170.518 2280 184.983 2340 192.444 2400 211.718 2460 231.257	1200	23.4705
1380 37.2794 1440 41.746 1500 50.1503 1560 54.8483 1620 63.647 1680 69.107 1740 79.9133 1800 88.393 1860 98.305 1920 115.63 1980 119.79 2040 128.71; 2100 143.30; 2160 156.224 2220 170.518 2280 184.98; 2340 192.444 2400 211.718 2460 231.25	1260	27.1667
1440 41.746 1500 50.1500 1560 54.8480 1620 63.647 1680 69.107 1740 79.9130 1860 98.305 1860 98.305 1920 115.60 1980 119.790 2040 128.712 2100 143.300 2160 156.22 2220 170.510 2280 184.980 2340 192.440 2400 211.710 2460 231.250 2520 241.840	1320	33.3196
1500 50.1503 1560 54.8483 1620 63.647 1680 69.107 1740 79.9133 1800 88.393 1860 98.305 1920 115.66 1980 119.79 2040 128.712 2100 143.303 2160 156.22 2220 170.513 2280 184.93 2340 192.444 22400 211.713 2460 231.25	1380	37.2794
1560 54.8488 1620 63.647 1680 69.107 1740 79.913 1800 88.393 1860 98.305 1920 115.66 1980 119.79 2040 128.71 2100 143.30 2160 156.22 2220 170.519 2280 184.93 2340 192.44 2400 211.71 2460 231.25 2520 241.846	1440	41.7461
1620 63.647 1680 69.107 1740 79.913 1800 88.393 1860 98.305 1920 115.66 1980 119.79 2040 128.71 2100 143.30 2160 156.22 2220 170.51 2280 184.93 2340 192.44 2400 211.71 2460 231.25 2520 241.846	1500	50.1505
1680 69.107 1740 79.913 1800 88.393 1860 98.305 1920 115.6 1980 119.79 2040 128.71 2100 143.30 2160 156.22 2220 170.51 2280 184.98 2340 192.44 2400 211.71 2460 231.25 2520 241.84	1560	54.8489
1740 79.9138 1800 88.393* 1860 98.305* 1920 115.68 1980 119.79 2040 128.712 2100 143.303 2160 156.224 2220 170.518 2280 184.983 2340 192.444 2400 211.718 2460 231.25*	1620	63.6477
1740 79.9138 1800 88.393* 1860 98.305* 1920 115.68 1980 119.79 2040 128.712 2100 143.303 2160 156.224 2220 170.518 2280 184.983 2340 192.444 2400 211.718 2460 231.25*		69.1077
1800 88.393 1860 98.305 1920 115.69 1980 119.799 2040 128.712 2100 143.309 2160 156.224 2220 170.519 2280 184.989 2340 192.444 2400 211.719 2460 231.25 2520 241.846		79.9139
1860 98.305 1920 115.69 1980 119.799 2040 128.712 2100 143.309 2160 156.224 2220 170.519 2280 184.989 2340 192.444 2400 211.719 2460 231.25		88.3931
1920 115.69 1980 119.79 2040 128.712 2100 143.303 2160 156.22 2220 170.513 2280 184.98 2340 192.444 2400 211.719 2460 231.25		98.3051
1980 119.798 2040 128.712 2100 143.308 2160 156.224 2220 170.518 2280 184.98 2340 192.448 2400 211.718 2460 231.25		
2040 128.712 2100 143.303 2160 156.224 2220 170.513 2280 184.93 2340 192.444 2400 211.713 2460 231.25 2520 241.846		
2100 143.309 2160 156.224 2220 170.519 2280 184.989 2340 192.444 2400 211.719 2460 231.25 2520 241.846		
2160 156.224 2220 170.518 2280 184.98 2340 192.444 2400 211.718 2460 231.25 2520 241.846		
2220 170.519 2280 184.983 2340 192.444 2400 211.719 2460 231.25 2520 241.846		
2280 184.983 2340 192.444 2400 211.713 2460 231.25 2520 241.846		
2340 192.444 2400 211.715 2460 231.25 2520 241.846		
2400 211.715 2460 231.25 2520 241.846		
2460 231.25 <sup>2</sup> 2520 241.846		
2520 241.846		
2580 270.05		
2640 288.443	2640	288.443

Table 2: the run time in seconds of the sequential matrix multiplication algorithm. The lack of fluctuation can be attributed to consistency provided by the algorithm running only on a single processor core of the same make and model.

Nothing unusual was encountered when testing the sequential algorithm. As expected, the sequential algorithm followed an  $O(n^3)$  curve as the size of the matrix increased. The sequential algorithm will now be compared to the parallel algorithm.

#### Parallel:

## **Changes made due to Critiques:**

The following changes were made to the parallel code based on feedback from the critiques:

- The code responsible for shifting columns up and shifting rows left were moved into two functions: ShiftUp() and ShiftLeft().
- The extra shifts up and right done after the last multiplication have been removed through the use of an if statement.
- Modular has been added to the code by creating functions for specific tasks in main.
  - The file I/O in main has been moved into functions.
  - The printing of the answer has been moved into functions.
  - The sending and receiving of sub-matrices in the initialization has been moved into functions.
- Some comments in main have been modified to be more descriptive and meaningful.

The changes made from the critiques have greatly increased the readability, modularity, and efficiency of the code for the parallel implementation.

#### **Run Times:**