CSC 458 Assignment 3

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Introduction

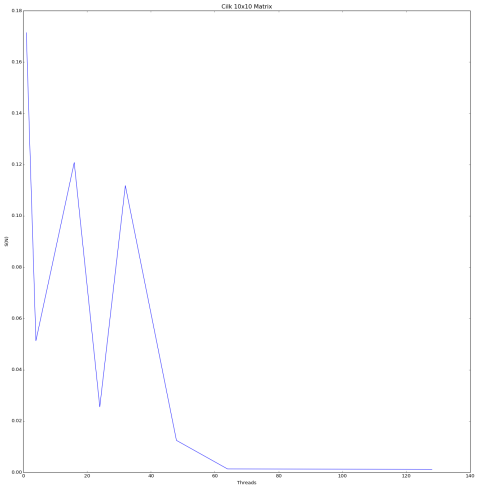
Assignment Three has us take a sequential program for solving systems of equations using gauss's method and make it parallel using both OpenMP and Cilk Plus. The code was tested using two matrices, one that was 10×10 and the other that was 2000×2000. The speedup of each method was then plotted to see how well they performed and to see if they were scalable.

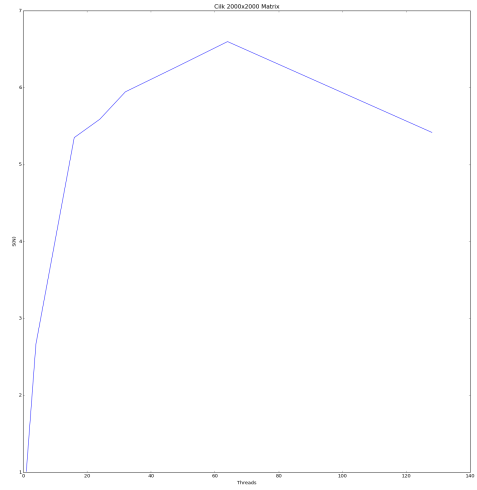
Data

Cilk

The Cilk implementation overall performed better than the sequential version of the code, and as you can see from the graphs it is moderatly scalable. While it is no where close to linear, there is only a dropoff when the number of threads exceeds the number of cores on the machine (visable in the plots for the value recorded with 128 threads). The graphs also show that for small data sets such as the 10x10 matrix the overhead of cilk's parallelization is more then the performace improvements and it has rather erratic and poor behavior.

Cilk did not achieve as high of a speedup as OpenMP did, however Cilk was more consistent in its growth. Because of this consistency I would say that Cilk is more scalable. Not only did it continue to increase in terms of speedup, but it could easily be modeled what adding more threads would do.





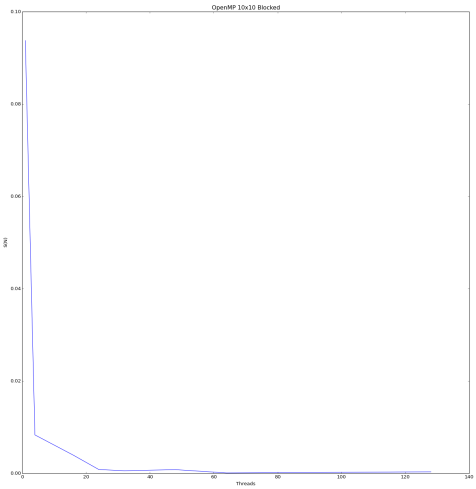
OpenMP

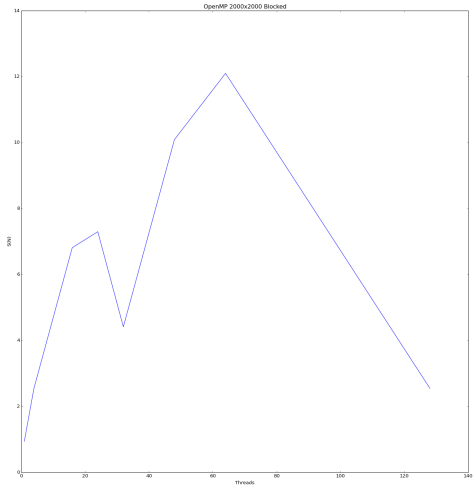
The OpenMP solution appeared to perform better with smaller numbers of threads, as well as being able to achieve the highest speedup. The OpenMP solution was by far much less scalable then the Cilk implementation was. One area where OpenMP did perform "better" was that for the lower matrix sizes

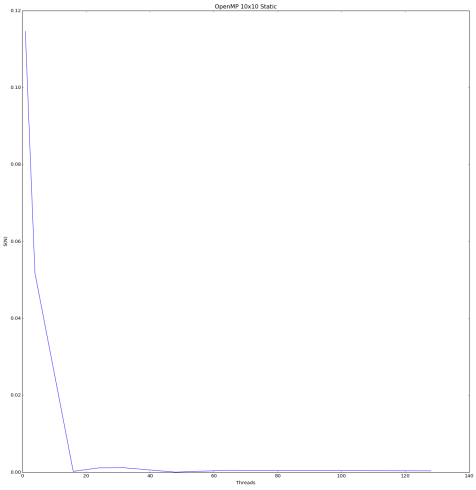
it exibited more consistent behavior, and was more predictable, however, it was still worse then the cilk implementatin in terms of speedup. All three task allocations saw a noticible drop in speedup for max threads numbers between 16 and 32. While the machine should have been able to accomodate those threads, it seems that how OpenMP was managing them caused the overhead for the non-powers of two to be much higher.

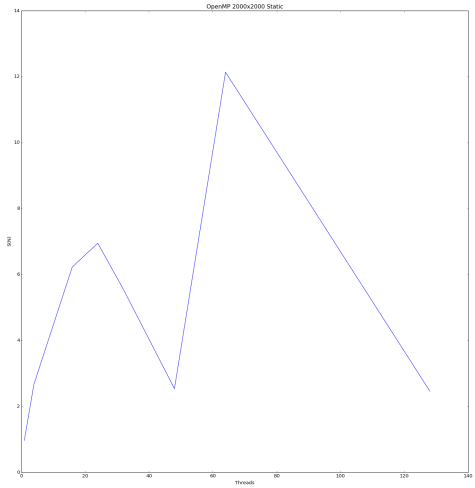
All three task allocations were very similar in terms of both performance and speedup, however in this case the blocked allocation appeared to work the best. The static allocation was the next best, and the dynamic was the worse. This was contrary to what I had expected. I had expected the static allocation to outperform the blocked allocation as the static allocation assigned the array rows in a cyclic manor, so throught the algoritm each thread was still doing work. Blocked being better then dynamic would be because of the overhead that is introduced by OpenMP for the dynamic assignment of tasks. This high overhead is consistent with the high overhead seen in the small array test for all three task allocations.

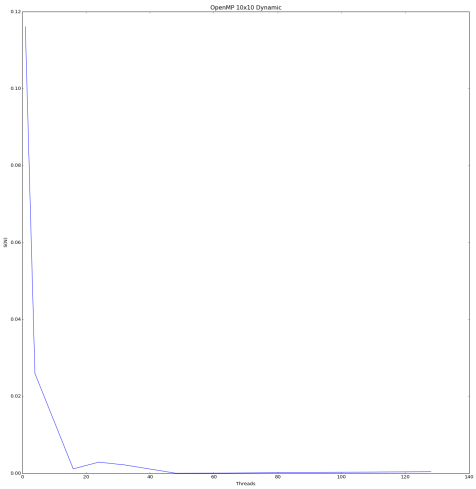
The main reason for my conclusion that the blocked allocation was better was because it took less of a hit between 16 and 32. All methods started out with around the same speedup, and they all had close to the same max speed up of around 12. I would like to run this test on larger sets of data to see if the same pattern emerges or if static allocation would end up pulling ahead.




OpenMP 2000x2000 Blocked
SPdU
Threads
0
2
4
6
8
10
12
14
0
20
40
60
80
100
120
140


OpenMP 10x10 Static
SPdU
Threads
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0
20
40
60
80
100
120
140


OpenMP 2000x2000 Static
SNU
Threads
0
2
4
6
8
10
12
14
0
20
40
60
80
100
120
140


OpenMP 10x10 Dynamic
SNU
Threads
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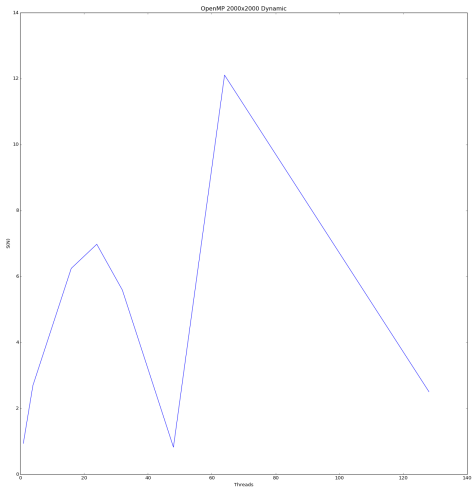
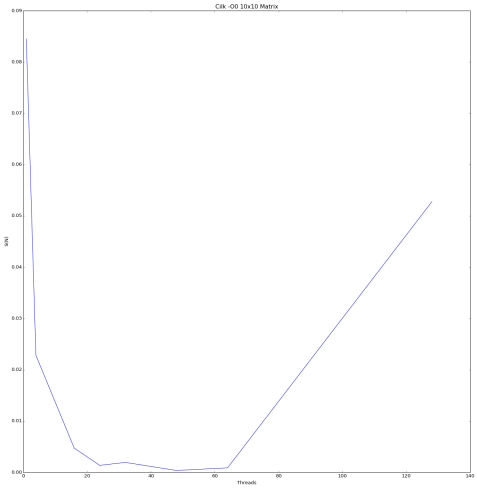
0.02
0.04
0.06
0.08
0.10
0.12
0
20
40
60
80
100
120
140



1 Optimization Levels

I also tested each algorithm compiled at varying optimization levels. Overall the more optimization I allowed the compiler to do, the less speedup was seen in the parallel implementations. At the highest optimization level, the sequential algorithm actually ran better than any of the Cilk runs. OpenMP still ran about 0.9 seconds faster.


Cilk -O0 10x10 Matrix
Time(s)
Threads
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
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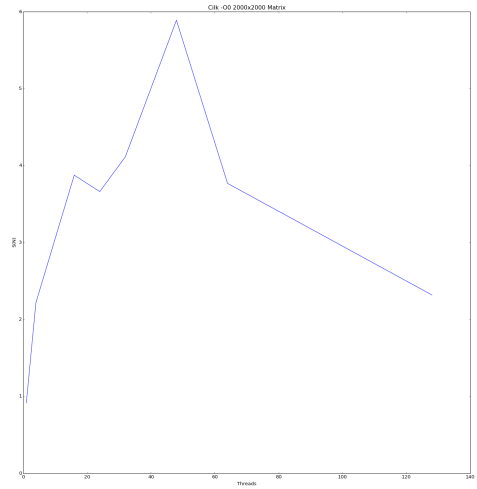
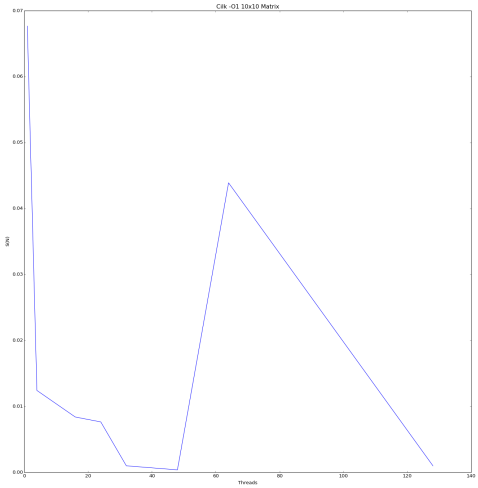
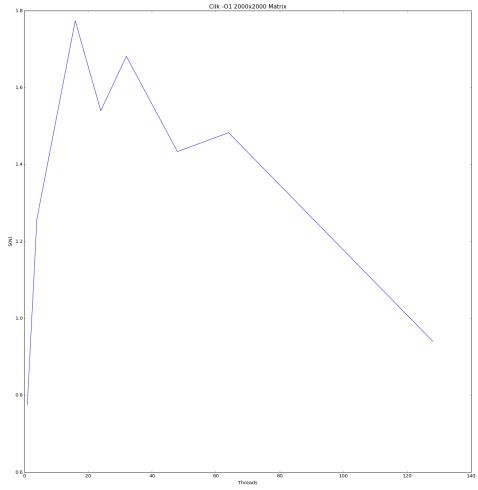
0.09
0
20
40
60
80
100
120
140


Cilk -O0 2000x2000 Matrix
Time(s)
Threads
0
1
2
3
4
5
6
0
20
40
60
80
100
120
140


Cilk -O1 10x10 Matrix
SpU
Threads
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0
20
40
60
80
100
120
140


Cilk -O1 2000x2000 Matrix
SpU
Threads
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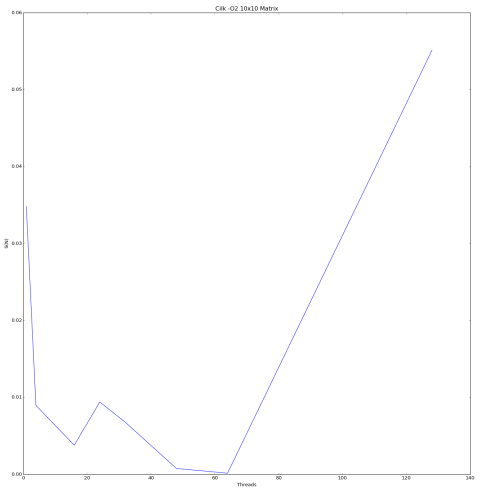
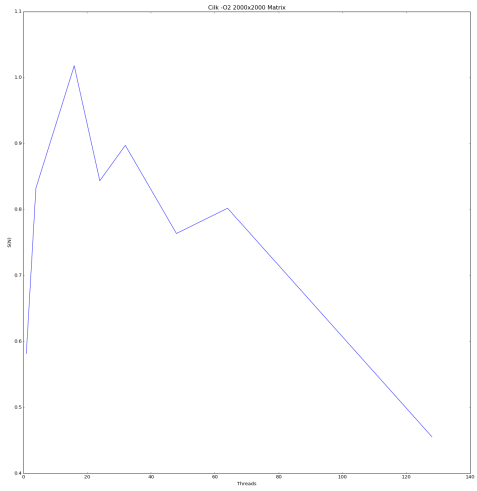
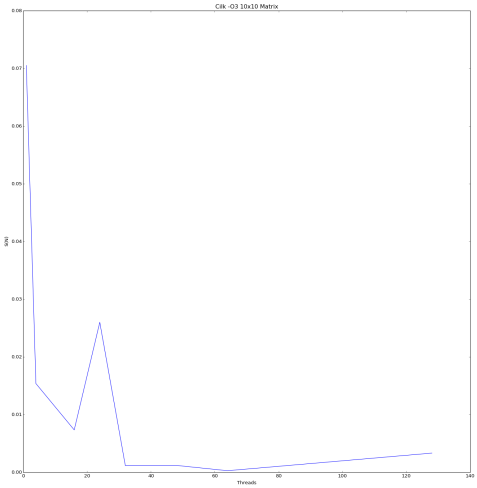
0.8
1.0
1.2
1.4
1.6
1.8
0
20
40
60
80
100
120
140


Cilk -O2 10x10 Matrix
0.06
0.05
0.04
0.03
0.02
0.01
0.00
SNI
0
20
40
60
80
100
120
140
Threads


Cilk -O2 2000x2000 Matrix
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
SNI
0
20
40
60
80
100
120
140
Threads


Cilk -O3 10x10 Matrix
Time(s)
Threads
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0.01
0.02
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0.04
0.05
0.06
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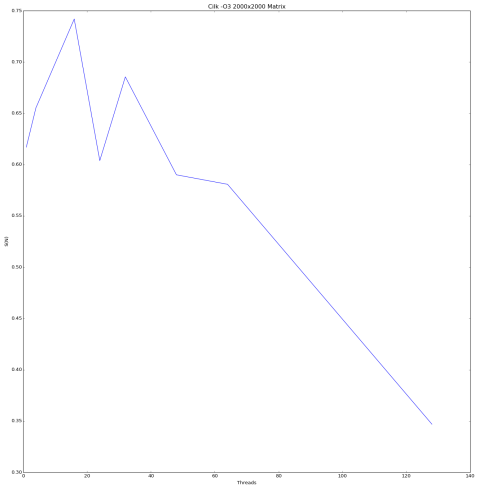
0.08
0
20
40
60
80
100
120
140


Cilk -O3 2000x2000 Matrix
Time(s)
Threads
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0.35
0.40
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0.70
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20
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60
80
100
120
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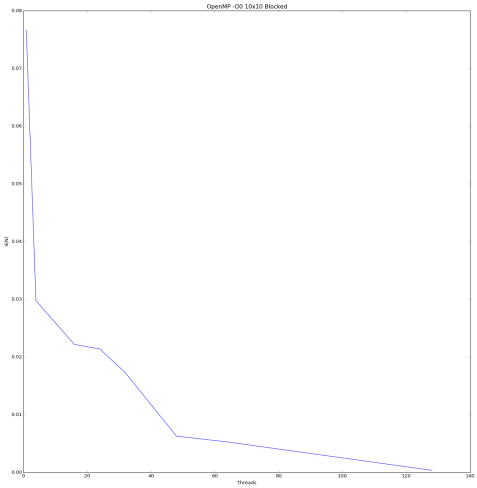
OpenMP -O0 10x10 Blocked
SPU
Threads
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
20
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60
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100
120
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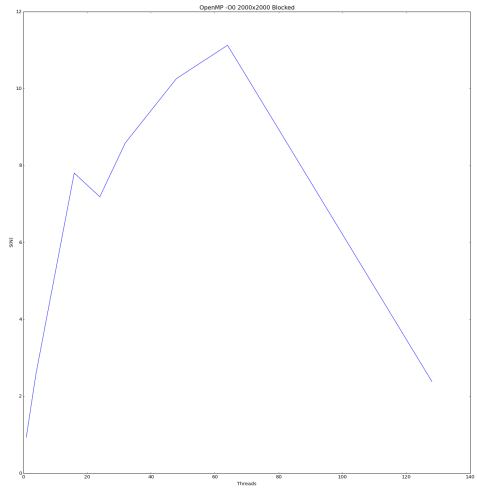
OpenMP -O0 2000x2000 Blocked
SPU
Threads
12
10
8
6
4
2
0
0
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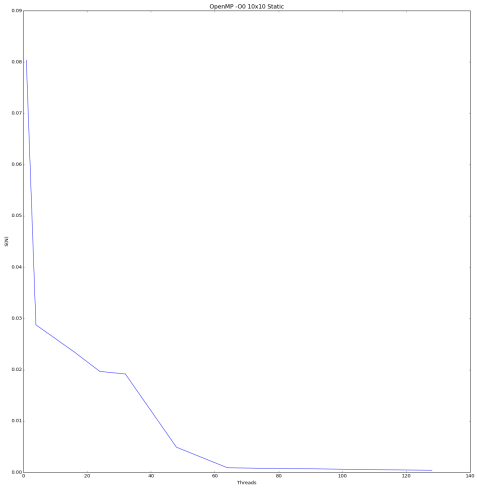
100
120
140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SPU
Threads
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0.08
0.07
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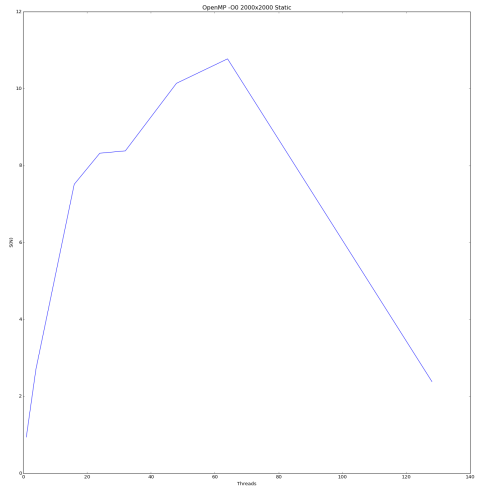
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SPU
Threads
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4
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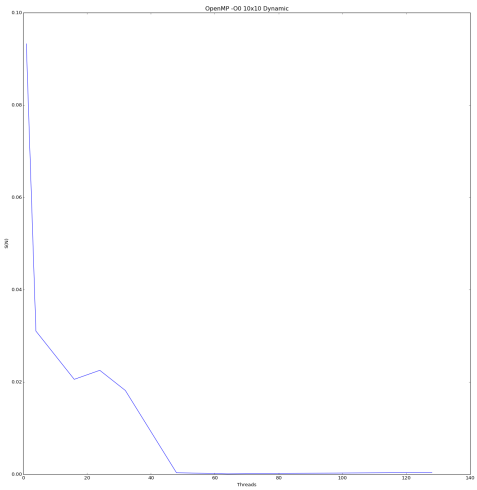
100
120
140


OpenMP -O0 10x10 Dynamic
SPU
Threads
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0.06
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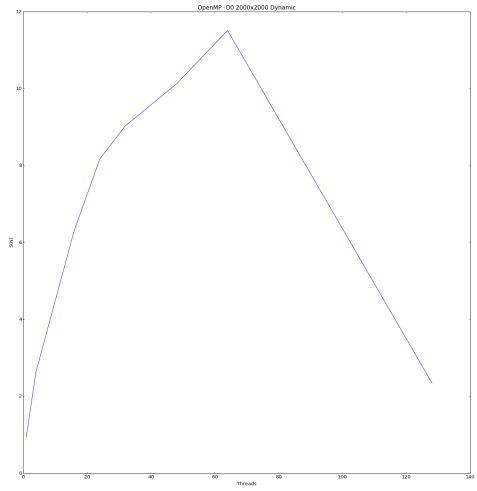
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Threads
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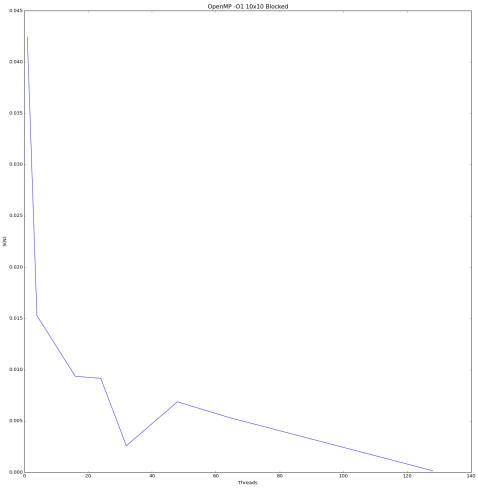
120
140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GNS
Threads
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0.040
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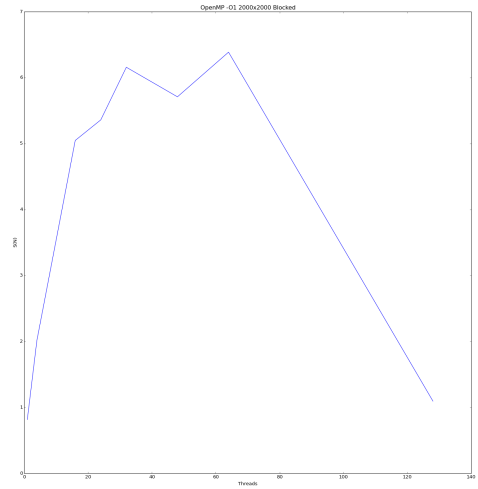
0.015
0.010
0.005
0.000
0
20
40
60
80
100
120
140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Threads
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120
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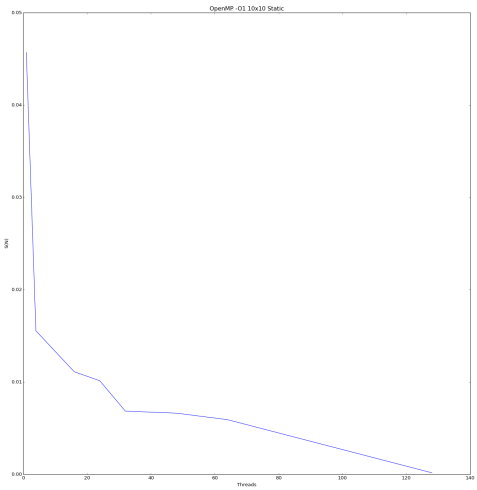
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SPEEDUP
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0.01
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0
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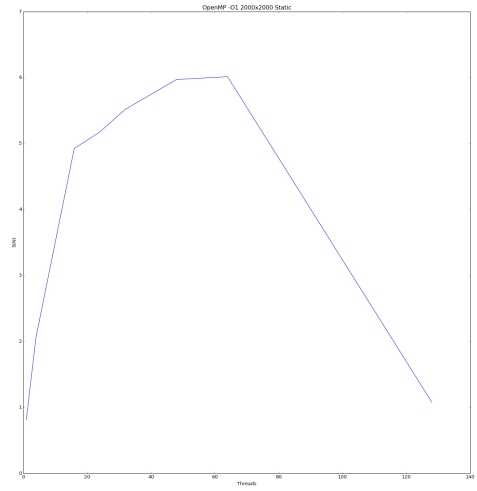
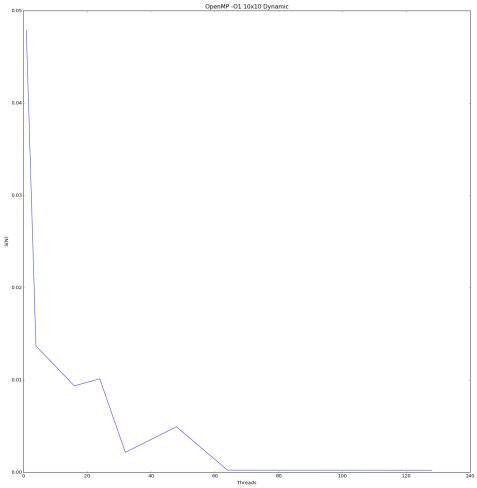
80
100
120
140


OpenMP -O1 2000x2000 Static
SPEEDUP
Threads
7
6
5
4
3
2
1
0
0
20
40
60
80
100
120
140


OpenMP -O1 10x10 Dynamic
SPEEDUP
Threads
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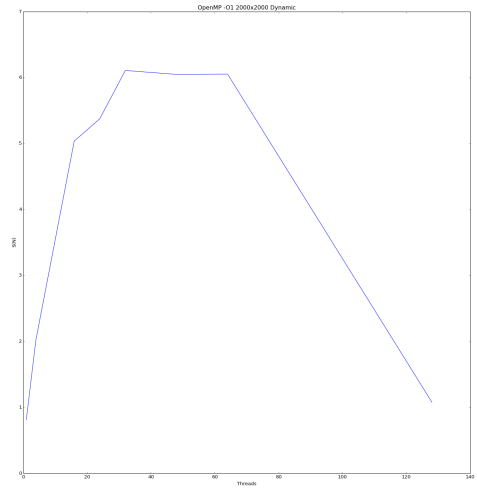
0.04
0.03
0.02
0.01
0.00
0
20
40
60
80
100
120
140


OpenMP -O1 2000x2000 Dynamic
SPEEDUP
Threads
7
6
5
4
3
2
1
0
0
20
40
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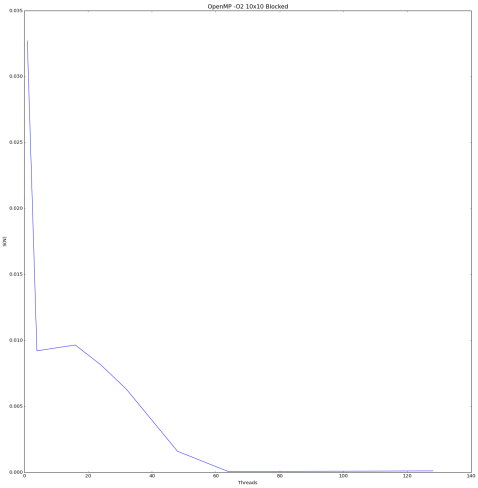
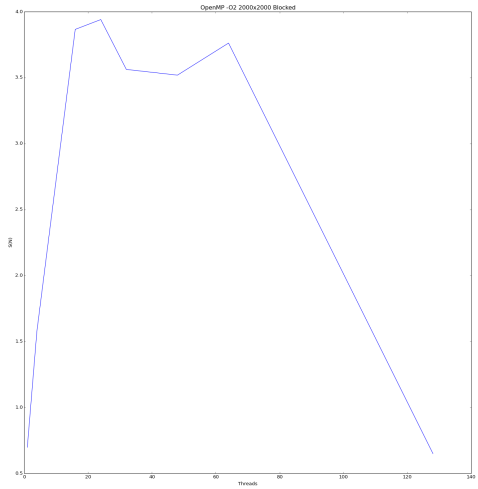
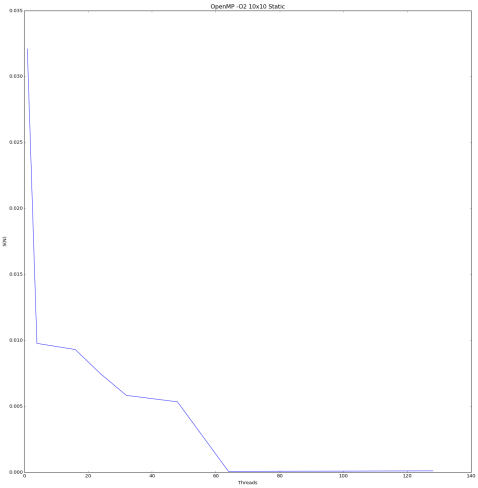
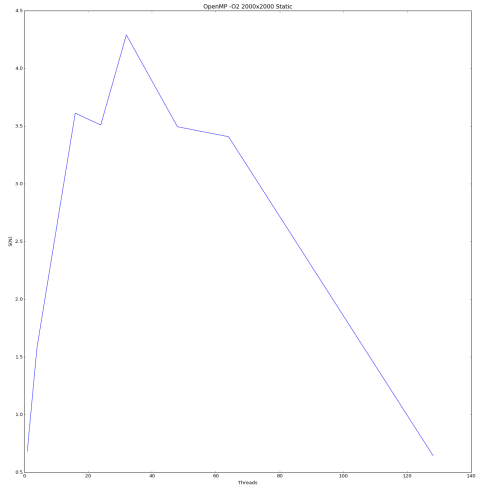
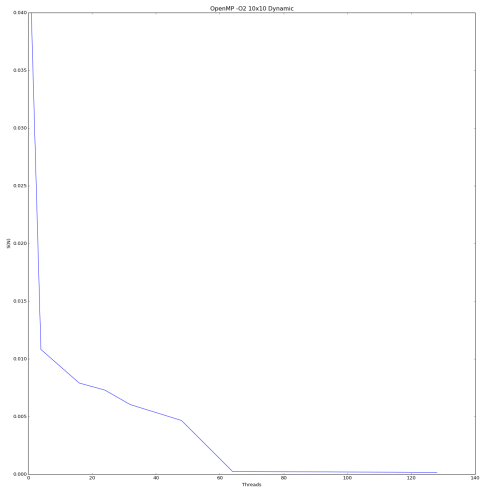
100
120
140

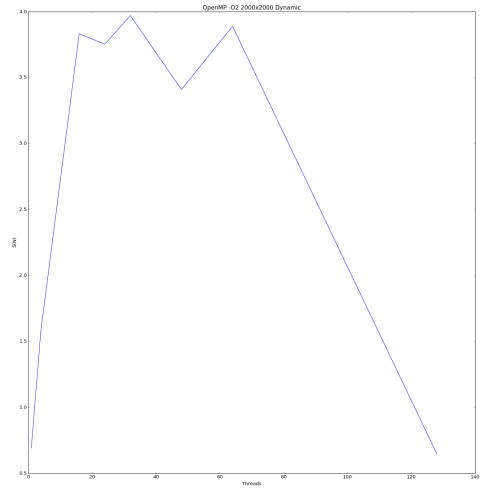

OpenMP -O2 10x10 Blocked
SPEED
Threads
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
20
40
60
80
100
120
140

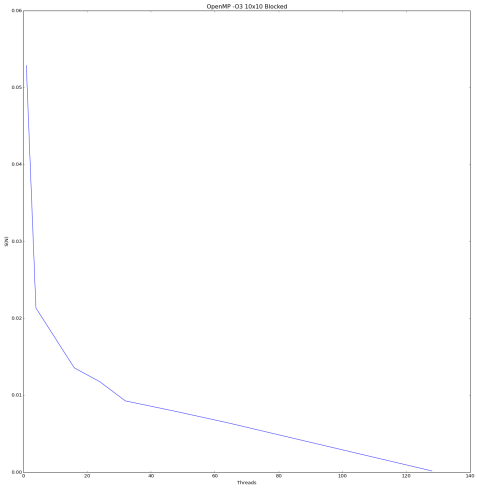

OpenMP -O2 2000x2000 Blocked
SPEED
Threads
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
20
40
60
80
100
120
140

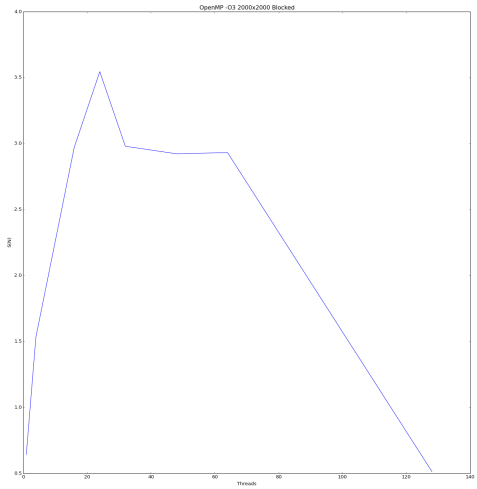

OpenMP -O2 10x10 Static
SPU
Threads
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
20
40
60
80
100
120
140

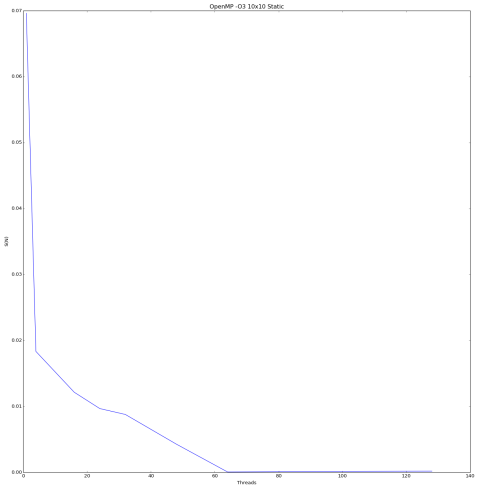

OpenMP -O2 2000x2000 Static
SPU
Threads
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
20
40
60
80
100
120
140

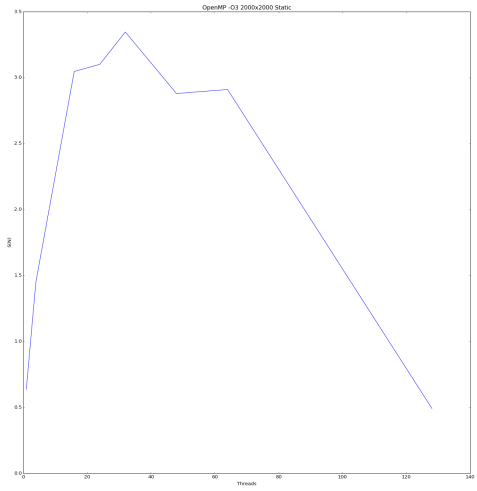

OpenMP -O2 10x10 Dynamic
Sec
Threads
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
20
40
60
80
100
120
140

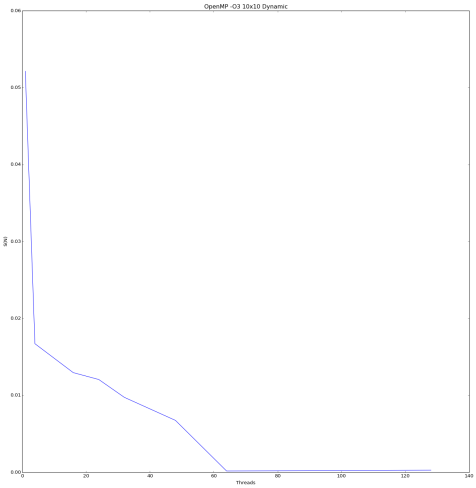

OpenMP -O2 2000x2000 Dynamic
SpU
Threads
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
20
40
60
80
100
120
140

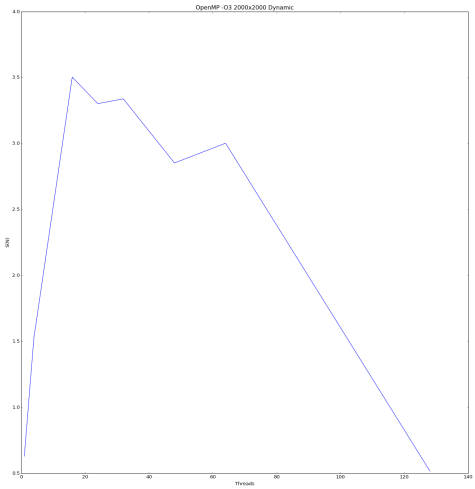

OpenMP -O3 10x10 Blocked
SPU
Threads
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0
20
40
60
80
100
120
140


OpenMP -O3 2000x2000 Blocked
SPU
Threads
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
20
40
60
80
100
120
140


OpenMP -O3 10x10 Static
Secs
Threads
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
20
40
60
80
100
120
140


OpenMP -O3 2000x2000 Static
Secs
Threads
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
120
140

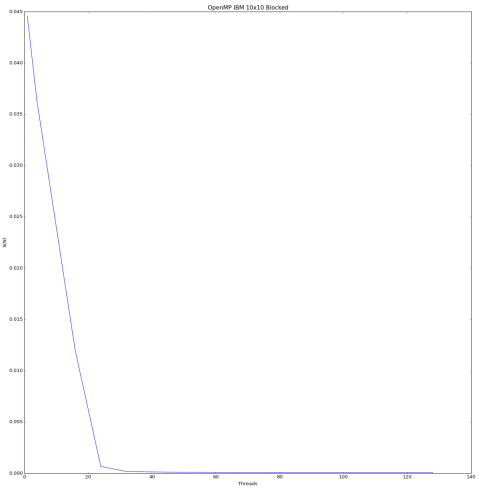


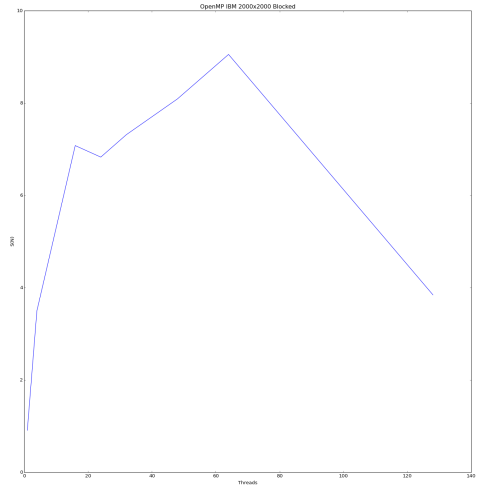


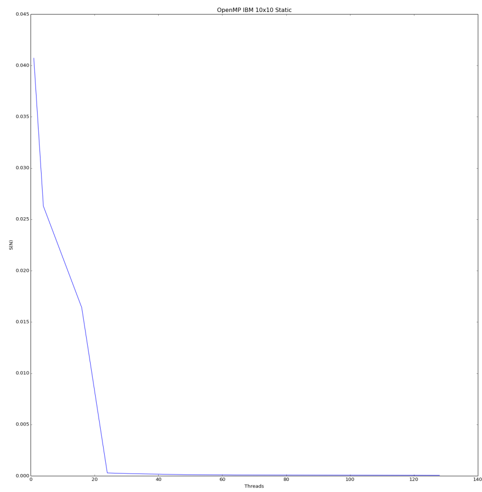
2 IBM

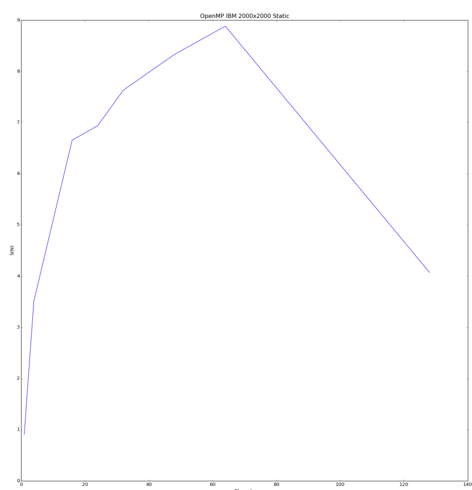
I tested my OpenMP implementation on the IBM machine as well and the results from that were more in line with what I expected. These results show that the dynamic allocation had the best performance, closely followed by the static allocation and the blocked allocation had the worst performance.

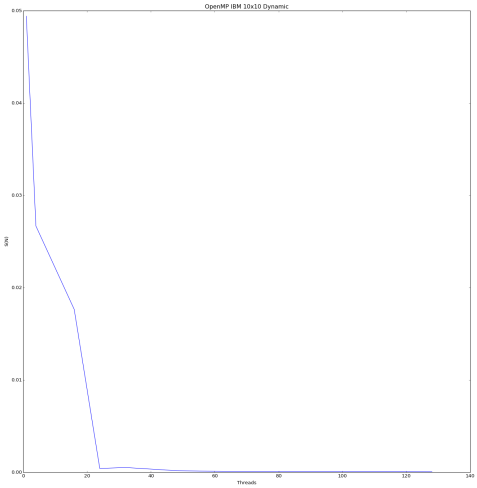
In this case the overhead of the dynamic allocation was not enough to reduce the benefits, and with that it makes sense that it would be the fastest. Then the other two were as expected. The static performed better because the data was cyclicly doled out to each thread, so they all kept working up until the end, as opposed to the blocked allocation where the lower number threads would finish working before the higher number threads would.

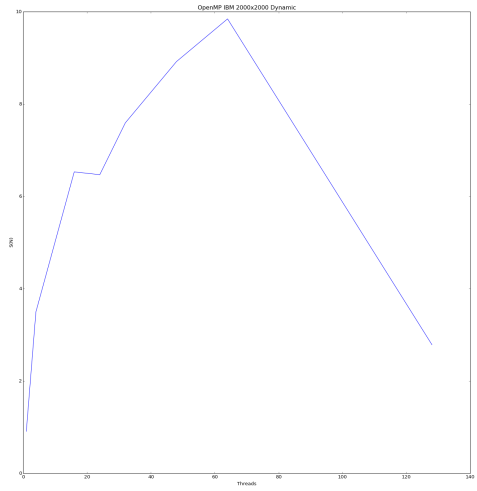





OpenMP IBM 10x10 Static
S(N)
Threads


OpenMP IBM 2000x2000 Static
S(N)
Threads





3 Conclusions