## High Performance Computing Assignment 2 Sripranav Suresh Kumar ss14432

The code for all the questions can be found at <a href="https://github.com/SripranavSureshKumar/HPCSpring2022/tree/main/homework2">https://github.com/SripranavSureshKumar/HPCSpring2022/tree/main/homework2</a>

## **System Specifications:**

```
Architecture:
                       x86_64
                      32-bit, 64-bit
CPU op-mode(s):
Byte Order:
                      Little Endian
CPU(s):
On-line CPU(s) list:
                      0-3
Thread(s) per core:
                      1
Core(s) per socket:
                       1
Socket(s):
NUMA node(s):
Vendor ID:
                      AuthenticAMD
CPU family:
                      23
Model:
Model name:
                      AMD EPYC Processor (with IBPB)
Stepping:
CPU MHz:
                      2894.560
BogoMIPS:
                      5789.12
Hypervisor vendor:
                      KVM
Virtualization type:
                      ful1
L1d cache:
                      32K
L1i cache:
                      64K
L2 cache:
                      512K
L3 cache:
                      8192K
NUMA node0 CPU(s):
                      0-3
```

## **Question 2**

Implemented Matrix Multiplication with blocking and with blocking along with OpenMP. Block size of 16 was too small and so experimented with block sizes till I finally settled on 32. The following results were seen when run on the above specified system.

Type Disention Time Gflop/s G8/s Error Reference 32 0.399036 5.110014 0.300000+00 Blockvise 32 0.399036 5.110014 0.2207112 0.800000+00 Blockvise 32 0.399036 5.110014 0.2207112 0.800000+00 Blockvise 64 0.337199 2.808079 17.70838 0.600000+00 Blockvise 64 0.337199 2.808079 17.70838 0.600000+00 Blockvise 64 0.337199 2.808079 17.70838 0.600000+00 Blockvice 96 0.338013 3.748315 30.298881 0.800000+00 Reference 96 0.539013 3.748315 30.298881 0.800000+00 BlockvicWP 96 0.613046 3.261281 26.386202 0.800000+00 Reference 128 0.537662 3.725234 30.293881 0.800000+00 Reference 128 0.310285 6.40788 52.135783 0.800000+00 BlockvicWP 128 0.310285 6.40788 52.135783 0.800000+00 Reference 128 0.537662 3.725234 30.034078 0.800000+00 Reference 128 0.316217 6.225740 51.01955 0.8000000+00 BlockvicWP 128 0.310325 15.003005 129.052233 0.000000+00 BlockvicWP 160 0.30000 6.063759 48.813241 0.000000+00 Blockvice 102 0.577840 3.478678 27.7074377 0.8000000+00 Blockvice 102 0.577840 3.478679 27.974377 0.8000000+00 Blockvice 102 0.578640 3.478679 27.974377 0.8000000+00 Blockvice 102 0.585868 5.60679 66.079002 0.000000+00 Blockvice 102 0.358586 5.60679 66.079002 0.000000+00 Blockvice 224 0.571946 3.479715 28.108247 0.8000000+00 Blockvice 224 0.571947 12.606785 10.124824 0.800000+00 Blockvice 236 0.33017 6.600000 4000000+00 Blockvice 236 0.33017 7.500000000000000000000000000000000000					
Block-Nome  32	Type	Dimension			
Block-ONP   32    0.837199    2.388056    10.708838    0.000000-00    8					
Block-OMP 64 0.324821 6.157729 50.031472 0.0000000+00 Block-OMP 64 0.427937 4.727210 38.424628 0.0000000+00 Block-OMP 64 0.533913 3.748315 38.298881 0.0000000+00 Block-OMP 76 0.533913 3.748315 38.298881 0.0000000+00 Block-OMP 76 0.15626 6.440788 52.155783 0.0000000+00 Block-OMP 76 0.15626 7.32574 30.034605 0.0000000+00 Block-OMP 76 0.3357062 3.735234 30.034605 0.0000000+00 Block-OMP 128 0.315217 6.326740 51.010955 0.0000000+00 Block-OMP 128 0.315217 6.326740 51.010955 0.0000000+00 Block-OMP 128 0.333952 15.000000 51.010955 0.0000000+00 Block-OMP 128 0.333952 15.000000 51.010955 0.0000000+00 Block-OMP 160 0.330909 6.063759 48.813261 0.0000000+00 Block-OMP 160 0.377863 10.183738 81.97909 0.0000000+00 Block-OMP 192 0.166355 12.083306 77.762584 0.0000000+00 Block-OMP 192 0.166355 12.083306 77.767907 0.0000000+00 Block-OMP 192 0.166355 12.083306 77.767907 0.0000000+00 Block-OMP 192 0.166355 12.083306 77.767907 0.0000000+00 Block-OMP 192 0.166355 12.083306 77.767923 0.0000000+00 Block-OMP 192 0.164355 12.083306 77.707923 0.0000000+00 Block-OMP 224 0.334577 5.979544 48.04995 0.0000000+00 Block-OMP 224 0.147167 14.072724 13.0000000+00 Block-OMP 224 0.147167 14.072724 13.0000000+00 Block-OMP 224 0.147167 14.072724 13.0000000+00 Block-OMP 224 0.157961 3.0000000+00 Block-OMP 256 0.157961 3.0000000+00 Block-OMP 256 0.157961 3.51376 28.303500 0.0000000+00 Block-OMP 256 0.157961 3.51376 28.303500 0.0000000+00 Block-OMP 280 0.167791 1.798884 70.0000000+00 Block-OMP 300 0.15791 1.798884 70.0000000+00 Block-OMP 300 0.15791 1.798884 70.0000000+00 Block-OMP 300 0.15791 1.798884 70.0000000+00 Block-OMP 300 0.158553 14.05553 14.05554 0.0000000+00 Block-OMP 300 0.158553 14.05553 14.05554 0.0000000+00 Block-OMP 300 0.158553 14.05553 14.05554 0.0000000+00 Block-OMP 300 0.158553 14.05553 14.05553 14.05553 14.05553 14.05553 14.05553 10.0000000+00 Block-OMP 480 0.153553 14.05553 14.05562 20.57568 0.0000000+00 Block-OMP 480 0.153553 14.05553 14.05562 20.57568 0.0000000+00 Block-OMP 480 0.153553 14.05553 14.05562 20.57568 0.0000000+00 Bloc					
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BlockWise   128	Block+OMP	96	0.613646	3.261281 26.362024 0.000000e+0	0
BlockWise   128	Deference	120	0 F27042	2 70522/ 20 02//05 0 000000	
Reference   168					
Block+OMP					
Block+OMP					
Reference   192					
Reference 192					
Block+OMP	BIOCK+OWL	100	0.19/083	.0.183/38 81.9/9090 0.000000e+0	
Block+OMP	Reference	192	0.577840	3.478679 27.974377 0.000000e+0	0
Reference 224	Blockwise			5.605679 45.079002 0.000000e+0	_
Blockwise   224   0.344577   5.979544   48.849965 0.808080e+08	Block+OMP	192	0.166355	L2.083306 97.169923 0.000000e+0	0
Blockwise   224   0.344577   5.979544   48.849965 0.808080e+08	Dofores		0 E740//	2 (07015 20 1000/7 0 000000-10	
Block+OMP   224   6.142167   14.072274   113.080776   6.000000e+00					=
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Block+OMP					
Block+OMP   256   0.159697   12.606785   101.248241   0.000000e+00					
Reference 288 0.571451 3.511376 28.188550 0.000000e+00 Blockwise 288 0.326148 6.152363 49.389799 0.000000e+00 Block+OMP 288 0.167791 11.958834 96.002858 0.000000e+00 Reference 320 0.573392 3.543156 28.433824 0.000000e+00 Blockwise 320 0.330855 6.140565 49.277555 0.000000e+00 Blockwise 320 0.150157 13.529916 108.577578 0.000000e+00 Blockwise 352 0.572484 3.504472 28.115423 0.000000e+00 Blockwise 352 0.333822 6.195543 49.705154 0.000000e+00 Blockwise 352 0.333822 6.195543 49.705154 0.000000e+00 Reference 384 0.576469 3.536067 28.362207 0.000000e+00 Blockwise 384 0.32760 6.125833 49.134282 0.000000e+00 Blockwise 384 0.216434 9.418251 75.542222 0.000000e+00 Reference 416 0.565433 3.564075 28.588361 0.000000e+00 Blockwise 416 0.326164 6.180192 49.560383 0.000000e+00 Blockwise 416 0.352164 6.180192 49.560383 0.000000e+00 Blockwise 448 0.611087 3.531360 28.313940 0.000000e+00 Reference 448 0.611087 3.531360 28.313940 0.000000e+00 Blockwise 448 0.342118 6.307679 50.574070 0.000000e+00 Reference 480 0.610339 3.623950 29.052003 0.000000e+00 Blockwise 480 0.361308 6.121760 49.976109 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Blockwise 544 0.360202 6.256136 50.141093 0.000000e+00 Blockwise 576 0.365672 6.271296 50.257468 0.0000000e+00					
Blockwise   288   0.326148   6.152363   49.380799   0.000000e+00	RIOCK+OWL	256	0.159697	12.606/85 101.248241 0.000000e+0	<b>о</b>
Blockwise   288   0.326148   6.152363   49.380799   0.000000e+00	Reference	288	0.571451	3.511376 28.188550 0.000000e+0	0
Reference 320 0.573392 3.543156 28.433824 8.000000e+00 Blockwise 320 0.330855 6.140505 49.277555 0.000000e+00 Block+OMP 320 0.150157 13.529916 108.577578 0.000000e+00 Blockwise 352 0.572484 3.504472 28.115423 0.000000e+00 Blockwise 352 0.323822 6.195543 49.705154 0.000000e+00 Blockwise 352 0.323822 6.195543 49.705154 0.000000e+00 Block+OMP 352 0.149114 13.454536 107.942070 0.000000e+00 Blockwise 384 0.576469 3.536067 28.362207 0.000000e+00 Blockwise 384 0.332760 6.125833 49.134282 0.000000e+00 Blockwise 384 0.216434 9.418251 75.542222 0.000000e+00 Block+OMP 384 0.216434 9.418251 75.542222 0.000000e+00 Blockwise 416 0.326164 6.180192 49.560383 0.000000e+00 Blockwise 416 0.326164 6.180192 49.560383 0.000000e+00 Blockwise 448 0.611087 3.531360 28.313940 0.000000e+00 Blockwise 448 0.342118 6.307679 50.574070 0.000000e+00 Blockwise 448 0.342118 6.307679 50.574070 0.000000e+00 Blockwise 448 0.153553 14.053661 112.679442 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076409 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076409 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076109 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Blockwise 544 0.631132 3.571123 28.621503 0.000000e+00 Blockwise 544 0.63132 3.571123 28.621503 0.000000e+00 Blockwise 544 0.63132 3.571123 28.621503 0.000000e+00 Blockwise 544 0.636562 6.256136 50.141093 0.000000e+00 Blockwise 546 0.366672 6.256136 50.141093 0.000000e+00 Blockwise 546 0.3665672 6.271296 50.257468 0.000000e+00 Blockwise 576 0.365672 6.271296 50.257468 0.000000e+00 Blockwise 576 0.365672 6.271296 50.257468 0.000000e+00					
Blockwise   320   0.330855   6.140505   49.277555   0.000000e+00   Block+OMP   320   0.150157   13.529916   108.577578   0.000000e+00   Blockwise   352   0.572484   3.504472   28.115423   0.000000e+00   Blockwise   352   0.323822   6.195543   49.705154   0.000000e+00   Block+OMP   352   0.149114   13.454536   107.942070   0.000000e+00   Blockwise   384   0.576469   3.536067   28.362207   0.000000e+00   Blockwise   384   0.321604   6.125833   49.134282   0.000000e+00   Blockwise   384   0.216434   9.418251   75.542222   0.000000e+00   Blockwise   416   0.326164   6.180192   49.560383   0.000000e+00   Block+OMP   416   0.158230   12.739392   102.160122   0.000000e+00   Blockwise   448   0.342118   6.307679   50.574070   0.000000e+00   Blockwise   448   0.342118   6.307679   50.574070   0.000000e+00   Blockwise   448   0.342118   6.307679   50.574070   0.000000e+00   Blockwise   480   0.361308   6.121760   49.076100   0.000000e+00   Blockwise   480   0.361308   6.121760   49.076100   0.000000e+00   Blockwise   512   0.613106   3.502632   28.075788   0.000000e+00   Blockwise   512   0.349156   6.150502   49.306118   0.000000e+00   Blockwise   512   0.349156   6.150502   49.306118   0.000000e+00   Blockwise   512   0.349156   6.150502   49.306118   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Block+OMP   544   0.162462   13.873071   111.188587   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Blockwise   545   0.366672   6.271296   5.257468   0.000000e+00   Blockwise   576   0.366672   6.271296   5.257468   0.000000e+00   Blockwise   576   0.366672   6.271296   5.257468   0.000000e+00   Blockwise   576   0.366672	Block+OMP	288	0.167791	1.958834 96.002858 0.000000e+0	0
Blockwise   320   0.330855   6.140505   49.277555   0.000000e+00   Block+OMP   320   0.150157   13.529916   108.577578   0.000000e+00   Blockwise   352   0.572484   3.504472   28.115423   0.000000e+00   Blockwise   352   0.323822   6.195543   49.705154   0.000000e+00   Block+OMP   352   0.149114   13.454536   107.942070   0.000000e+00   Blockwise   384   0.576469   3.536067   28.362207   0.000000e+00   Blockwise   384   0.321604   6.125833   49.134282   0.000000e+00   Blockwise   384   0.216434   9.418251   75.542222   0.000000e+00   Blockwise   416   0.326164   6.180192   49.560383   0.000000e+00   Block+OMP   416   0.158230   12.739392   102.160122   0.000000e+00   Blockwise   448   0.342118   6.307679   50.574070   0.000000e+00   Blockwise   448   0.342118   6.307679   50.574070   0.000000e+00   Blockwise   448   0.342118   6.307679   50.574070   0.000000e+00   Blockwise   480   0.361308   6.121760   49.076100   0.000000e+00   Blockwise   480   0.361308   6.121760   49.076100   0.000000e+00   Blockwise   512   0.613106   3.502632   28.075788   0.000000e+00   Blockwise   512   0.349156   6.150502   49.306118   0.000000e+00   Blockwise   512   0.349156   6.150502   49.306118   0.000000e+00   Blockwise   512   0.349156   6.150502   49.306118   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Block+OMP   544   0.162462   13.873071   111.188587   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Blockwise   545   0.366672   6.271296   5.257468   0.000000e+00   Blockwise   576   0.366672   6.271296   5.257468   0.000000e+00   Blockwise   576   0.366672   6.271296   5.257468   0.000000e+00   Blockwise   576   0.366672	Deference.			2 5/245/ 22 /2222/ 2 22222	
Block+OMP   320					
Blockwise   352   0.323822   6.195543   49.795154   0.000000e+00   Block+OMP   352   0.149114   13.454536   107.942070   0.000000e+00   Blockwise   384   0.576469   3.536067   28.362207   0.000000e+00   Blockwise   384   0.32760   6.125833   49.134282   0.000000e+00   Block+OMP   384   0.216434   9.418251   75.542222   0.000000e+00   Blockwise   416   0.565433   3.564975   28.588361   0.000000e+00   Blockwise   416   0.326164   6.180192   49.560383   0.000000e+00   Blockwise   416   0.158230   12.739392   102.160122   0.000000e+00   Blockwise   448   0.611087   3.531360   28.313940   0.000000e+00   Blockwise   448   0.342118   6.307679   50.574070   0.000000e+00   Blockwise   448   0.153553   14.053561   112.679442   0.000000e+00   Blockwise   480   0.361308   6.121760   49.076109   0.000000e+00   Blockwise   480   0.361308   6.121760   49.076109   0.000000e+00   Blockwise   480   0.349165   6.15602   29.571167   0.000000e+00   Blockwise   512   0.613106   3.502632   28.075788   0.000000e+00   Blockwise   512   0.155181   13.838577   110.924845   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Blockwise   545   0.636056   3.605600   28.893274   0.000000e+00   Blockwise   576   0.636057   6.271296   50.257468   0.000000e+00   0.000000e+00   Blockwise   576   0.365672   6.271296   50.257468   0.000000e+00   0.000000e+00   Blockwise   576   0.365672   6.271296   50.257468   0.000000e+00   0.000000e+00   0.000000e+00   0.0000000e+00   0.00000000000000000000000000000000					
Blockwise   352   0.323822   6.195543   49.795154   0.000000e+00   Block+OMP   352   0.149114   13.454536   107.942070   0.000000e+00   Blockwise   384   0.576469   3.536067   28.362207   0.000000e+00   Blockwise   384   0.32760   6.125833   49.134282   0.000000e+00   Block+OMP   384   0.216434   9.418251   75.542222   0.000000e+00   Blockwise   416   0.565433   3.564975   28.588361   0.000000e+00   Blockwise   416   0.326164   6.180192   49.560383   0.000000e+00   Blockwise   416   0.158230   12.739392   102.160122   0.000000e+00   Blockwise   448   0.611087   3.531360   28.313940   0.000000e+00   Blockwise   448   0.342118   6.307679   50.574070   0.000000e+00   Blockwise   448   0.153553   14.053561   112.679442   0.000000e+00   Blockwise   480   0.361308   6.121760   49.076109   0.000000e+00   Blockwise   480   0.361308   6.121760   49.076109   0.000000e+00   Blockwise   480   0.349165   6.15602   29.571167   0.000000e+00   Blockwise   512   0.613106   3.502632   28.075788   0.000000e+00   Blockwise   512   0.155181   13.838577   110.924845   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Blockwise   545   0.636056   3.605600   28.893274   0.000000e+00   Blockwise   576   0.636057   6.271296   50.257468   0.000000e+00   0.000000e+00   Blockwise   576   0.365672   6.271296   50.257468   0.000000e+00   0.000000e+00   Blockwise   576   0.365672   6.271296   50.257468   0.000000e+00   0.000000e+00   0.000000e+00   0.0000000e+00   0.00000000000000000000000000000000					
## Block+OMP   352					
Reference 384 0.576469 3.536067 28.362207 0.0000000e+00 Blockwise 384 0.332760 6.125833 49.134282 0.000000e+00 Block+OMP 384 0.216434 9.418251 75.542222 0.000000e+00 Reference 416 0.565433 3.564975 28.588361 0.000000e+00 Blockwise 416 0.326164 6.180192 49.560383 0.000000e+00 Block+OMP 416 0.158230 12.739392 102.160122 0.000000e+00 Reference 448 0.611087 3.531360 28.313940 0.000000e+00 Blockwise 448 0.342118 6.307679 50.574070 0.000000e+00 Blockwise 448 0.153553 14.053561 112.679442 0.000000e+00 Reference 480 0.610339 3.623950 29.052003 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076109 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076109 0.000000e+00 Block+OMP 480 0.147063 15.040062 120.571167 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Block+OMP 512 0.155181 13.838577 110.924845 0.000000e+00 Blockwise 544 0.631132 3.571123 28.621503 0.000000e+00 Blockwise 544 0.360262 6.256136 50.141093 0.000000e+00 Blockwise 544 0.360262 13.873071 111.188587 0.000000e+00 Blockwise 544 0.360262 6.256136 50.141093 0.000000e+00 Blockwise 576 0.636056 3.605400 28.893274 0.000000e+00 Blockwise 576 0.365672 6.271296 50.257468 0.000000e+00					-
Blockwise   384   0.332760   6.125833   49.134282   0.000000e+00   Block+OMP   384   0.216434   9.418251   75.542222   0.000000e+00   Blockwise   416   0.565433   3.564975   28.588361   0.000000e+00   Blockwise   416   0.326164   6.180192   49.560383   0.000000e+00   Block+OMP   416   0.158230   12.739392   102.160122   0.000000e+00   Blockwise   448   0.611087   3.531360   28.313940   0.000000e+00   Blockwise   448   0.342118   6.307679   50.574070   0.000000e+00   Block+OMP   448   0.153553   14.053561   112.679442   0.000000e+00   Blockwise   480   0.361308   6.121760   49.076109   0.000000e+00   Blockwise   480   0.361308   6.121760   49.076109   0.000000e+00   Block+OMP   480   0.147063   15.040062   120.571167   0.000000e+00   Blockwise   512   0.349156   6.150502   49.300118   0.000000e+00   Block+OMP   512   0.155181   13.838577   110.924845   0.000000e+00   Block+OMP   544   0.631132   3.571123   28.621503   0.000000e+00   Blockwise   544   0.360262   6.256136   50.141093   0.000000e+00   Block+OMP   544   0.162462   13.873071   111.188587   0.000000e+00   Block+OMP   544   0.162462   13.873071   111.188587   0.000000e+00   Block+OMP   544   0.162462   13.873071   111.188587   0.0000000e+00   Blockwise   576   0.636056   3.605400   28.893274   0.000000e+00   Blockwise   576   0.6360572   6.271296   50.257468   0.000000e+00   Blockwise   576   0.365672   6.271296   50.257468   0.0000000e+00   Blockwise   576   0.365672   6.271296   50.257468   0.00000000e+00   Blockwise	BIOCKTOMP				• 
## Block+OMP   384   0.216434   9.418251   75.542222   0.000000e+00	Reference	384	0.576469	3.536067 28.362207 0.000000e+0	0
Reference 416 0.565433 3.564975 28.588361 0.000000e+00 Blockwise 416 0.326164 6.180192 49.560383 0.000000e+00 Block+OMP 416 0.158230 12.739392 102.160122 0.000000e+00 Blockwise 448 0.611087 3.531360 28.313940 0.000000e+00 Blockwise 448 0.342118 6.307679 50.574070 0.000000e+00 Block+OMP 448 0.153553 14.053561 112.679442 0.000000e+00 Block+OMP 448 0.153553 14.053561 112.679442 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076109 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076109 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Block+OMP 512 0.155181 13.838577 110.924845 0.000000e+00 Blockwise 544 0.631132 3.571123 28.621503 0.000000e+00 Blockwise 544 0.360262 6.256136 50.141093 0.000000e+00 Blockwise 544 0.360262 13.873071 111.188587 0.000000e+00 Block+OMP 544 0.162462 13.873071 111.188587 0.000000e+00 Block+OMP 545 0.636056 3.605400 28.893274 0.000000e+00 Blockwise 576 0.636056 3.605400 28.893274 0.000000e+00 Blockwise 576 0.365672 6.271296 50.257468 0.000000e+00	Blockwise	384	0.332760		0
Blockwise 416 0.326164 6.180192 49.560383 0.000000e+00 Block+OMP 416 0.158230 12.739392 102.160122 0.000000e+00  Reference 448 0.611087 3.531360 28.313940 0.000000e+00 Blockwise 448 0.342118 6.307679 50.574070 0.000000e+00 Block+OMP 448 0.153553 14.053561 112.679442 0.000000e+00 Blockwise 480 0.610339 3.623950 29.052003 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076109 0.000000e+00 Blockwise 480 0.147063 15.040062 120.571167 0.000000e+00 Blockwise 512 0.613106 3.502632 28.075788 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Blockwise 512 0.351123 28.621503 0.000000e+00 Block+OMP 512 0.155181 13.838577 110.924845 0.000000e+00 Blockwise 544 0.360262 6.256136 50.141093 0.000000e+00 Blockwise 544 0.360262 6.256136 50.141093 0.000000e+00 Block+OMP 544 0.162462 13.873071 111.188587 0.000000e+00 Blockwise 576 0.636056 3.605400 28.893274 0.000000e+00 Blockwise 576 0.636056 3.605400 28.893274 0.000000e+00 Blockwise 576 0.365672 6.271296 50.257468 0.000000e+00	Block+OMP	384	0.216434	9.418251 75.542222 0.000000e+0	0
Blockwise 416 0.326164 6.180192 49.560383 0.000000e+00 Block+OMP 416 0.158230 12.739392 102.160122 0.000000e+00  Reference 448 0.611087 3.531360 28.313940 0.000000e+00 Blockwise 448 0.342118 6.307679 50.574070 0.000000e+00 Block+OMP 448 0.153553 14.053561 112.679442 0.000000e+00 Blockwise 480 0.610339 3.623950 29.052003 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076109 0.000000e+00 Blockwise 480 0.147063 15.040062 120.571167 0.000000e+00 Blockwise 512 0.613106 3.502632 28.075788 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Blockwise 512 0.351123 28.621503 0.000000e+00 Block+OMP 512 0.155181 13.838577 110.924845 0.000000e+00 Blockwise 544 0.360262 6.256136 50.141093 0.000000e+00 Blockwise 544 0.360262 6.256136 50.141093 0.000000e+00 Block+OMP 544 0.162462 13.873071 111.188587 0.000000e+00 Blockwise 576 0.636056 3.605400 28.893274 0.000000e+00 Blockwise 576 0.636056 3.605400 28.893274 0.000000e+00 Blockwise 576 0.365672 6.271296 50.257468 0.000000e+00	Reference		0.565433	3.564975 28.588361 0.000000-+0	 9
## Block+OMP					
Blockwise 448 0.342118 6.307679 50.574070 0.000000e+00 Block+OMP 448 0.153553 14.053561 112.679442 0.000000e+00  Reference 480 0.610339 3.623950 29.052003 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076109 0.000000e+00 Block+OMP 480 0.147063 15.040062 120.571167 0.000000e+00  Reference 512 0.613106 3.502632 28.075788 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Block+OMP 512 0.155181 13.838577 110.924845 0.000000e+00  Reference 544 0.631132 3.571123 28.621503 0.000000e+00 Blockwise 544 0.360262 6.256136 50.141093 0.000000e+00 Blockwise 544 0.162462 13.873071 111.188587 0.000000e+00  Reference 576 0.636056 3.605400 28.893274 0.000000e+00 Blockwise 576 0.365672 6.271296 50.257468 0.000000e+00					
Blockwise 448 0.342118 6.307679 50.574070 0.000000e+00 Block+OMP 448 0.153553 14.053561 112.679442 0.000000e+00  Reference 480 0.610339 3.623950 29.052003 0.000000e+00 Blockwise 480 0.361308 6.121760 49.076109 0.000000e+00 Block+OMP 480 0.147063 15.040062 120.571167 0.000000e+00  Reference 512 0.613106 3.502632 28.075788 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Block+OMP 512 0.155181 13.838577 110.924845 0.000000e+00  Reference 544 0.631132 3.571123 28.621503 0.000000e+00 Blockwise 544 0.360262 6.256136 50.141093 0.000000e+00 Blockwise 544 0.162462 13.873071 111.188587 0.000000e+00  Reference 576 0.636056 3.605400 28.893274 0.000000e+00 Blockwise 576 0.365672 6.271296 50.257468 0.000000e+00					
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Reference 512 0.613106 3.502632 28.075788 0.000000e+00 Blockwise 512 0.349156 6.150502 49.300118 0.000000e+00 Block+OMP 512 0.155181 13.838577 110.924845 0.000000e+00  Reference 544 0.631132 3.571123 28.621503 0.000000e+00 Blockwise 544 0.360262 6.256136 50.141093 0.000000e+00 Block+OMP 544 0.162462 13.873071 111.188587 0.000000e+00  Reference 576 0.636056 3.605400 28.893274 0.000000e+00 Blockwise 576 0.365672 6.271296 50.257468 0.000000e+00					
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Blockwise 576 0.365672 6.271296 50.257468 0.000000e+00					<u></u>
	Reference	576	0.636056		
Block+OMP 576 0.160068 14.326670 114.812342 0.000000e+00					
	Block+OMP	576	0.160068	4.326670 114.812342 0.000000e+0	0

Reference	1600	4.493046	1.823262	45.938321	0.000000e+00
Blockwise	1600	1.427500	5.738703		0.000000e+00
Block+OMP	1600	0.721255	11.357984		0.000000e+00
Reference	1632	4.756683	1.827621	45.547261	0.000000e+00
Blockwise	1632	1.527862	5.689921		0.000000e+00
Block+OMP	1632	0.562206	15.463042		0.000000e+00
Reference	1664	4.828822	1.908309	46.566480	0.000000e+00
Blockwise	1664	1.584045	5.817314		0.000000e+00
Block+OMP	1664	0.608523	15.143034		0.000000e+00
Reference	1696	5.172940	1.886123	42.949776	0.000000e+00
Blockwise	1696	1.818413	5.365558		0.000000e+00
Block+OMP	1696	0.914095	10.673730		0.000000e+00
Reference	1728	5.754754	1.793224	45.863814	0.000000e+00
Blockwise	1728	1.801077	5.729661		0.000000e+00
Block+OMP	1728	1.024908	10.068772		0.000000e+00
Reference	1760	6.096265	1.788563	46.979009	0.000000e+00
Blockwise	1760	1.857808	5.869041		0.000000e+00
Block+OMP	1760	0.730822	14.919581		0.000000e+00
Reference	1792	6.330224	1.818130	45.845990	0.000000e+00
Blockwise	1792	2.009439	5.727553		0.000000e+00
Block+OMP	1792	0.975146	11.802512		0.000000e+00
Reference	1824	6.944850	1.747598	46.561719	0.000000e+00
Blockwise	1824	2.086429	5.817026		0.000000e+00
Block+OMP	1824	1.010448	12.011311		0.000000e+00
Reference	1856	7.186231	1.779356	45.840630	0.000000e+00
Blockwise	1856	2.232735	5.726993		0.000000e+00
Block+OMP	1856	1.188677	10.757221		0.000000e+00
Reference	1888	7.360568	1.828625	46.134502	0.000000e+00
Blockwise	1888	2.335232	5.763760		0.000000e+00
Block+OMP	1888	1.295957	10.385933		0.000000e+00
Reference	1920	7.739237	1.829092	46.537374	0.000000e+00
Blockwise	1920	2.434714	5.814144		0.000000e+00
Block+OMP	1920	0.984625	14.376812		0.000000e+00
Reference	1952	8.346586	1.782217	46.489904	0.000000e+00
Blockwise	1952	2.561080	5.808262		0.000000e+00
Block+OMP	1952	1.053002	14.126689		0.000000e+00
Reference	1984	8.693782	1.796579	44.805647	0.000000e+00
Blockwise	1984	2.790173	5.597884		0.000000e+00
Block+OMP	1984	1.156234	13.508564		0.000000e+00

## **Question 4**

Implemented both Jacobi and Gauss - Seidel 2D Smoothing using openMP while using #ifdef so that the code runs either with or without openMP depending on the presence on the -fopenmp flag. The following results were seen when run on the above specified system.

Jacobi 2D

Size	Iterations	Time	
100	5000	0.141498	
200	5000	0.565315	
300	5000	1.441683	
400	5000	2.654483	
500	5000	4.431369	
600	5000	5.834869	
700	5000	8.533784	
800	5000 :	12.972822	
900	5000 :	16.085515	
1000	5000 :	21.001232	

Gauss - Seidel 2D

Size	Iterations	Time	
100	5000	0.134732	
200	5000	0.329541	
300	5000	0.721481	
400	5000	1.306637	
500	5000	1.966796	
600	5000	3.223839	
700	5000	4.802923	
800	5000	6.254761	
900	5000	8.057718	
1000	5000	9.761805	