High Performance Computing
Assignment 2
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The code for all the questions can be found at
https://github.com/SripranavSureshKumar/HPCSpring2022/tree/main/homework2

System Specifications:

```
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
CPU(s):                4
On-line CPU(s) list:   0-3
Thread(s) per core:    1
Core(s) per socket:    1
Socket(s):             4
NUMA node(s):          1
Vendor ID:             AuthenticAMD
CPU family:            23
Model:                 1
Model name:            AMD EPYC Processor (with IBPB)
Stepping:              2
CPU MHz:               2894.560
BogoMIPS:              5789.12
Hypervisor vendor:     KVM
Virtualization type:   full
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	Dimension	Time	Gflop/s	GB/s	Error
Reference	32	0.540957	3.697205	30.501940	0.000000e+00
Blockwise	32	0.390935	5.116014	42.207112	0.000000e+00
Block+OMP	32	0.837199	2.388950	19.708838	0.000000e+00
Reference	64	0.535930	3.732125	30.323513	0.000000e+00
Blockwise	64	0.324821	6.157720	50.031472	0.000000e+00
Block+OMP	64	0.422937	4.729210	38.424828	0.000000e+00
Reference	96	0.533913	3.748315	30.298881	0.000000e+00
Blockwise	96	0.310285	6.449788	52.135783	0.000000e+00
Block+OMP	96	0.613646	3.261281	26.362024	0.000000e+00
Reference	128	0.537062	3.725234	30.034695	0.000000e+00
Blockwise	128	0.316217	6.326940	51.010955	0.000000e+00
Block+OMP	128	0.133352	15.003068	120.962233	0.000000e+00
Reference	160	0.581959	3.448768	27.762584	0.000000e+00
Blockwise	160	0.330989	6.063759	48.813261	0.000000e+00
Block+OMP	160	0.197083	10.183738	81.979090	0.000000e+00
Reference	192	0.577840	3.478679	27.974377	0.000000e+00
Blockwise	192	0.358586	5.605679	45.079002	0.000000e+00
Block+OMP	192	0.166355	12.083306	97.169923	0.000000e+00
Reference	224	0.571946	3.497915	28.108247	0.000000e+00
Blockwise	224	0.334577	5.979544	48.049905	0.000000e+00
Block+OMP	224	0.142167	14.072274	113.080776	0.000000e+00
Reference	256	0.572813	3.514700	28.227431	0.000000e+00
Blockwise	256	0.331127	6.080045	48.830360	0.000000e+00
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	6.140505	49.277555	0.000000e+00
Block+OMP	320	0.150157	13.529916	108.577578	0.000000e+00
Reference	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
Reference	384	0.576469	3.536067	28.362207	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
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
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
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
Block+OMP	576	0.160068	14.326670	114.812342	0.000000e+00

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Reference      1600    4.493046    1.823262    14.595211 0.000000e+00
Blockwise      1600    1.427500    5.738703    45.938321 0.000000e+00
Block+OMP      1600    0.721255   11.357984    90.920666 0.000000e+00
------------------------------------------------------------------------
Reference      1632    4.756683    1.827621    14.629930 0.000000e+00
Blockwise      1632    1.527862    5.689921    45.547261 0.000000e+00
Block+OMP      1632    0.562206   15.463042   123.780137 0.000000e+00
------------------------------------------------------------------------
Reference      1664    4.828822    1.908309    15.275650 0.000000e+00
Blockwise      1664    1.584045    5.817314    46.566480 0.000000e+00
Block+OMP      1664    0.608523   15.143034   121.217072 0.000000e+00
------------------------------------------------------------------------
Reference      1696    5.172940    1.886123    15.097883 0.000000e+00
Blockwise      1696    1.818413    5.365558    42.949776 0.000000e+00
Block+OMP      1696    0.914095   10.673730    85.440184 0.000000e+00
------------------------------------------------------------------------
Reference      1728    5.754754    1.793224    14.354091 0.000000e+00
Blockwise      1728    1.801077    5.729661    45.863814 0.000000e+00
Block+OMP      1728    1.024908   10.068772    80.596793 0.000000e+00
------------------------------------------------------------------------
Reference      1760    6.096265    1.788563    14.316631 0.000000e+00
Blockwise      1760    1.857808    5.869041    46.979009 0.000000e+00
Block+OMP      1760    0.730822   14.919581   119.424462 0.000000e+00
------------------------------------------------------------------------
Reference      1792    6.330224    1.818130    14.553157 0.000000e+00
Blockwise      1792    2.009439    5.727553    45.845990 0.000000e+00
Block+OMP      1792    0.975146   11.802512    94.472783 0.000000e+00
------------------------------------------------------------------------
Reference      1824    6.944850    1.747598    13.988452 0.000000e+00
Blockwise      1824    2.086429    5.817026    46.561719 0.000000e+00
Block+OMP      1824    1.010448   12.011311    96.143173 0.000000e+00
------------------------------------------------------------------------
Reference      1856    7.186231    1.779356    14.242515 0.000000e+00
Blockwise      1856    2.232735    5.726993    45.840630 0.000000e+00
Block+OMP      1856    1.188677   10.757221    86.104139 0.000000e+00
------------------------------------------------------------------------
Reference      1888    7.360568    1.828625    14.636748 0.000000e+00
Blockwise      1888    2.335232    5.763760    46.134502 0.000000e+00
Block+OMP      1888    1.295957   10.385933    83.131472 0.000000e+00
------------------------------------------------------------------------
Reference      1920    7.739237    1.829092    14.640356 0.000000e+00
Blockwise      1920    2.434714    5.814144    46.537374 0.000000e+00
Block+OMP      1920    0.984625   14.376812   115.074403 0.000000e+00
------------------------------------------------------------------------
Reference      1952    8.346586    1.782217    14.265039 0.000000e+00
Blockwise      1952    2.561080    5.808262    46.489904 0.000000e+00
Block+OMP      1952    1.053002   14.126689   113.071409 0.000000e+00
------------------------------------------------------------------------
Reference      1984    8.693782    1.796579    14.379874 0.000000e+00
Blockwise      1984    2.790173    5.597884    44.805647 0.000000e+00
Block+OMP      1984    1.156234   13.508564   108.122985 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