ICSI/IECE404 Programming Exercise 2
(20 points Due EOD Monday, 18 November)

Evaluating the Throughput Performance and a "Roofline" Performance Model for the N x N Matrix Multiplication Algorithm on an Intel Xeon 6338 Processor

Collecting and analyzing Performance Metrics for the square matrix multiplication algorithm:

1. Upload the instructor provided C programming language matrix multiplication benchmark code file, *PE2_source.c*, to your NetID account on our Xeon Gold 6338 system in the ITS Data Center(lmm.its.albany.edu).

2. Load the GCC 12.2.1 compiler. You must use this compiler for all benchmark data collected in PE2.

3. Configure, compile and run the *PE2_source.c* code capturing total elapsed time results for each of the nine test configurations listed in the test results table shown below. Each test configuration uses a unique combination of prescribed matrix dimension size, N, and test parameter settings for the # of outer loops. You will need to edit the PE2.source.c code "define" statements before compiling the code for each test configuration. GCC 12.2.1 compiler command line settings will be the same for all test configurations:

   gcc pe2.source.c -O3 -fopenmp -march=icelake-server

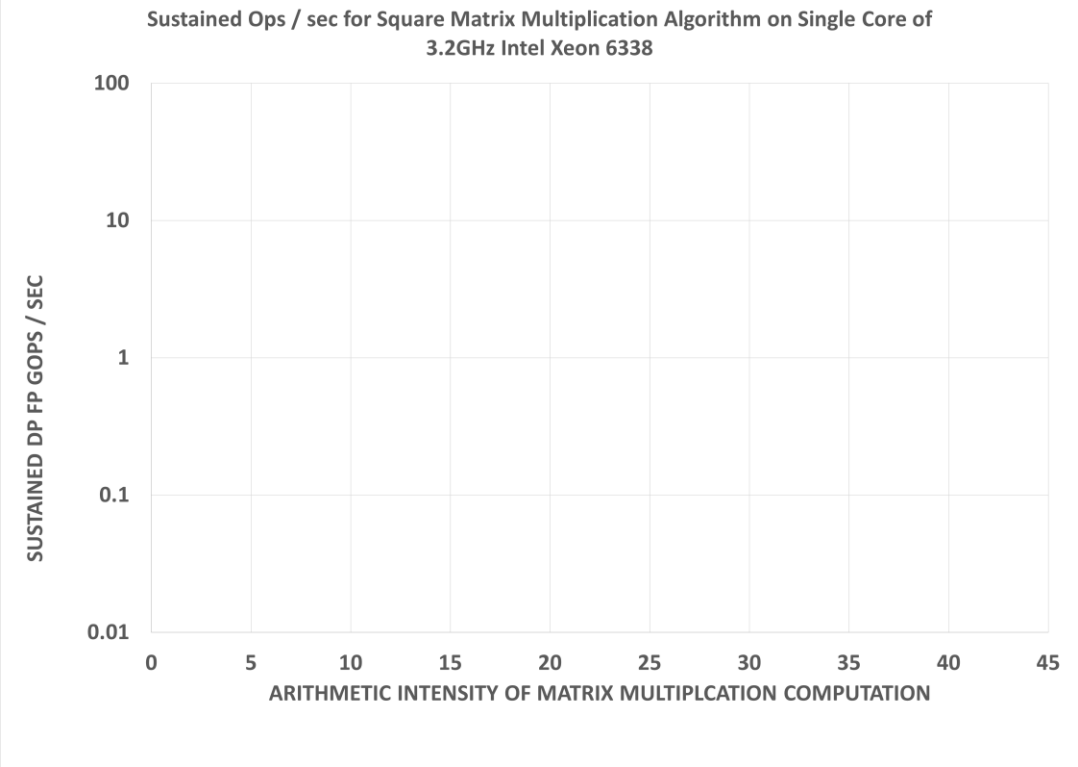
   An Excel spreadsheet template (*PE2_Results_Template.xlsx*) containing a copy of the table is provided for you to record & document the captured total elapsed benchmark time, benchmark performance metrics values computed by the benchmark source code and printed to the console. You will, however, need to evaluate the sustained DP FP Ops/sec, Ops/sec and Arithmetic Intensity column values.

	Processor		Algorithm Characteristics				Test Case Parameters			Results	
Test Configuration	CPU	Clock Speed, Cycles per second	Matrix Dimension, N (for NxN Square Matrix Multiplication Algorithm)	Estimated Total # of Arithmetic Ops neede to solve 1 iteration of matrix multication	Estimated Memory Footprint, Bytes	Algorithmic Arithmetic Intensity, Ops/Byte	GCC Compiler settings for Matrix Multiplication Algorithm. (re run without extras)	Number of outer accuracy improvement loops	Total Elapsed benchmark time, sec	Evaluated sustained performance, DP FP Ops per sec	Ops/cycle
1	Xeon 6338	3.20E+09	2				gcc PE4_source.c -O3 -fopenmp -march=icelake-server	1.00E+08			
2	Xeon 6338	3.20E+09	4				gcc PE4_source.c -O3 -fopenmp -march=icelake-server	1.00E+07			
3	Xeon 6338	3.20E+09	8				gcc PE4_source.c -O3 -fopenmp -march=icelake-server	1.00E+07			
4	Xeon 6338	3.20E+09	16				gcc PE4_source.c -O3 -fopenmp -march=icelake-server	1.00E+06			
5	Xeon 6338	3.20E+09	32				gcc PE4_source.c -O3 -fopenmp -march=icelake-server	1.00E+05			
6	Xeon 6338	3.20E+09	64				gcc PE4_source.c -O3 -fopenmp -march=icelake-server	1.00E+05			
7	Xeon 6338	3.20E+09	128				gcc PE4_source.c -O3 -fopenmp -march=icelake-server	1.00E+04			
8	Xeon 6338	3.20E+09	256				gcc PE4_source.c -O3 -fopenmp -march=icelake-server	1.00E+03			
9	Xeon 6338	3.20E+09	512				gcc PE4_source.c -O3 -fopenmp -march=icelake-server	1.00E+02			

Roofline Performance Analysis of the N x N matrix multiplication algorithm

4. From the benchmark data collected and values evaluated in the PE2_Results_Template spreadsheet, generate a single Excel semi-log plot (example shown below) of the sustained DP FP Ops/sec versus Arithmetic Intensity. Semi-log plots use a logarithmic scale on the vertical axis (DP FP Ops/sec) , and linear scale on the horizontal axis (A.I.)

   Label the axes, and include units. Mark and annotate the region of the plots where the matrix multiplication benchmark performance is communication limited, and region where benchmark performance is processor computation limited.



Materials submitted to Blackboard for scoring:

1) **Rename your copy of the of the Excel spreadsheet template file to include your name or initials and the problem designator: *"your_name_PE2_Results.xlsx"* . The spreadsheet should contain your collected performance data, other values in the table evaluated in part 3, and the semi-log plot of Sustained DP FP Ops/sec versus arithmetic intensity to. Upload the file in Brightspace. *(5 points will be deducted if you do not upload your completed/populated results Excel file.)***

2) **Create a written report, in PDF or MS Word format, which includes images of your completed/populated data table and semi-log plot, and answers to the following processor microarchitecture and performance analysis and upload it to Brightspace *(5 points will be deducted if you do not upload a written report)***

    a. **From the configurations used, and data collected or evaluated in part 3 estimate how many parallel, arithmetic pipelines in the Execution Engine of the 6338's microarchitecture are *active* during execution of the matrix multiplication benchmark. Explain and justify your answer. *Be quantitative, and use only the configuration information, data collected or evaluated*.**

    b. **From the semi-log Roofline Model plot created in part 4, explain and quantitatively justify the reason for the slope of the sustained DP FP**

Ops/sec versus arithmetic intensity plot in the region identified as:

i. **Computation limited**

ii. **Communication limited**