CS6230: Parallel Programming & HPC

Fall 2023

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GEMM: General Matrix Multiplication

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1. CPU - Openmp Results
    1.1 CADE Lab Performance
        Test Case 1: Ni = 8,192, Nj = 8,192, Nk = 16
        Test Case 2: Ni = 4096, Nj = 4096, Nk = 64
        Test Case 3: Ni = 2048, Nj = 2048, Nk = 256
        Test Case 4: Ni = 1024, Nj = 1024, Nk = 1024
        Test Case 5: Ni = 256, Nj = 256, Nk = 16,384
        Test Case 6: Ni = 64, Nj = 64, Nk = 262,144
        Test Case 7: Ni = 16, Nj = 16, Nk = 4,194,304
        Test Case 8: Ni = 8,991, Nj = 8,991, Nk = 37
        Test Case 9: Ni = 2,997, Nj = 2,997, Nk = 11
        Test Case 10: Ni = 999, Nj = 999, Nk = 999
        Test Case 11: Ni = 333, Nj = 333, Nk = 8,991
        Test Case 12: Ni = 111, Nj = 111, Nk = 80,919
        Test Case 13: Ni = 37, Nj = 37, Nk = 728,271
    1.2 Lonepeak Performance - TODO Awaiting JOB Results
        Test Case 1: Ni = 8,192, Nj = 8,192, Nk = 16
        Test Case 2: Ni = 4096, Nj = 4096, Nk = 64
        Test Case 3: Ni = 2048, Nj = 2048, Nk = 256
        Test Case 4: Ni = 1024, Nj = 1024, Nk = 1024
        Test Case 5: Ni = 256, Nj = 256, Nk = 16,384
        Test Case 6: Ni = 64, Nj = 64, Nk = 262,144
        Test Case 7: Ni = 16, Nj = 16, Nk = 4,194,304
        Test Case 8: Ni = 8,991, Nj = 8,991, Nk = 37
        Test Case 9: Ni = 2,997, Nj = 2,997, Nk = 11
        Test Case 10: Ni = 999, Nj = 999, Nk = 999
        Test Case 11: Ni = 333, Nj = 333, Nk = 8,991
        Test Case 12: Ni = 111, Nj = 111, Nk = 80,919
        Test Case 13: Ni = 37, Nj = 37, Nk = 728,271
2. GPU - CUDA Results
        Test Case 1: Ni = 8,192, Nj = 8,192, Nk = 16
        Test Case 2: Ni = 4096, Nj = 4096, Nk = 64
        Test Case 3: Ni = 2048, Nj = 2048, Nk = 256
        Test Case 4: Ni = 1024, Nj = 1024, Nk = 1024
        Test Case 5: Ni = 256, Nj = 256, Nk = 16,384
        Test Case 6: Ni = 64, Nj = 64, Nk = 262,144
        Test Case 7: Ni = 16, Nj = 16, Nk = 4,194,304
        Test Case 8: Ni = 8,991, Nj = 8,991, Nk = 37
        Test Case 9: Ni = 2,997, Nj = 2,997, Nk = 11
        Test Case 10: Ni = 999, Nj = 999, Nk = 999
        Test Case 11: Ni = 333, Nj = 333, Nk = 8,991
        Test Case 12: Ni = 111, Nj = 111, Nk = 80,919
        Test Case 13: Ni = 37, Nj = 37, Nk = 728,271
    1.2 Lonepeak Performance - TODO Awaiting on JOB Results

Test Case 1: Ni = 8,192, Nj = 8,192, Nk = 16
Test Case 2: Ni = 4096, Nj = 4096, Nk = 64
Test Case 3: Ni = 2048, Nj = 2048, Nk = 256
Test Case 4: Ni = 1024, Nj = 1024, Nk = 1024
Test Case 5: Ni = 256, Nj = 256, Nk = 16,384
Test Case 6: Ni = 64, Nj = 64, Nk = 262,144
Test Case 7: Ni = 16, Nj = 16, Nk = 4,194,304
Test Case 8: Ni = 8,991, Nj = 8,991, Nk = 37
Test Case 9: Ni = 2,997, Nj = 2,997, Nk = 11
Test Case 10: Ni = 999, Nj = 999, Nk = 999
Test Case 11: Ni = 333, Nj = 333, Nk = 8,991
Test Case 12: Ni = 111, Nj = 111, Nk = 80,919
Test Case 13: Ni = 37, Nj = 37, Nk = 728,271
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1. OpenMP CADE Lab Output
2. OpenMP CADE Lonepeak Output Pending
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1. CPU - Openmp Results

1.1 CADE Lab Performance

Test Case 1: Ni = 8,192, Nj = 8,192, Nk = 16

Variants	Performance (GFLOPs)
A x B	115.82
At x B	115.25
A x Bt	116.50
At x Bt	115.55

Test Case 2: Ni = 4096, Nj = 4096, Nk = 64

Variants	Performance (GFLOPs)
A x B	151.04
At x B	149.09
A x Bt	151.06
At x Bt	148.55

Test Case 3: Ni = 2048, Nj = 2048, Nk = 256

Variants	Performance (GFLOPs)
A x B	156.02
At x B	153.43
A x Bt	153.58
At x Bt	149.81

Test Case 4: Ni = 1024, Nj = 1024, Nk = 1024

Variants	Performance (GFLOPs)
A x B	151.71
At x B	139.84
A x Bt	140.23
At x Bt	128.75

Test Case 5: Ni = 256, Nj = 256, Nk = 16,384

Variants	Performance (GFLOPs)
A x B	116.80
At x B	94.12
A x Bt	99.68
At x Bt	83.24

Test Case 6: Ni = 64, Nj = 64, Nk = 262,144

Variants	Performance (GFLOPs)
A x B	75.42
At x B	44.55
A x Bt	53.60
At x Bt	38.24

Test Case 7: Ni = 16, Nj = 16, Nk = 4,194,304

Variants	Performance (GFLOPs)
A x B	27.61
At x B	16.79
A x Bt	20.25
At x Bt	15.54

Test Case 8: Ni = 8,991, Nj = 8,991, Nk = 37

Variants	Performance (GFLOPs)
A x B	154.00
At x B	153.67
A x Bt	154.66
At x Bt	153.26

Test Case 9: Ni = 2,997, Nj = 2,997, Nk = 11

Variants	Performance (GFLOPs)
A x B	162.81
At x B	162.82
A x Bt	160.02
At x Bt	156.99

Test Case 10: Ni = 999, Nj = 999, Nk = 999

Variants	Performance (GFLOPs)
A x B	149.65
At x B	138.33
A x Bt	138.35
At x Bt	130.56

Test Case 11: Ni = 333, Nj = 333, Nk = 8,991

Variants	Performance (GFLOPs)
A x B	127.90
At x B	108.62
A x Bt	110.52
At x Bt	93.98

Test Case 12: Ni = 111, Nj = 111, Nk = 80,919

Variants	Performance (GFLOPs)
A x B	89.64
At x B	54.52
A x Bt	74.65
At x Bt	47.69

Test Case 13: Ni = 37, Nj = 37, Nk = 728,271

Variants	Performance (GFLOPs)
A x B	70.45
At x B	40.67
A x Bt	46.03
At x Bt	45.77

1.2 Lonepeak Performance - TODO Awaiting JOB Results

Test Case 1: Ni = 8,192, Nj = 8,192, Nk = 16

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 2: Ni = 4096, Nj = 4096, Nk = 64

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 3: Ni = 2048, Nj = 2048, Nk = 256

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 4: Ni = 1024, Nj = 1024, Nk = 1024

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 5: Ni = 256, Nj = 256, Nk = 16,384

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 6: Ni = 64, Nj = 64, Nk = 262,144

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 7: Ni = 16, Nj = 16, Nk = 4,194,304

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 8: Ni = 8,991, Nj = 8,991, Nk = 37

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 9: Ni = 2,997, Nj = 2,997, Nk = 11

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 10: Ni = 999, Nj = 999, Nk = 999

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 11: Ni = 333, Nj = 333, Nk = 8,991

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 12: Ni = 111, Nj = 111, Nk = 80,919

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 13: Ni = 37, Nj = 37, Nk = 728,271

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

2. GPU - CUDA Results

Test Case 1: Ni = 8,192, Nj = 8,192, Nk = 16

Variants	Performance (GFLOPs)
A x B	798.48
At x B	801.63
A x Bt	846.51
At x Bt	840.31

Test Case 2: Ni = 4096, Nj = 4096, Nk = 64

Variants	Performance (GFLOPs)
A x B	1750.96
At x B	1863.15
A x Bt	1788.23
At x Bt	1672.41

Test Case 3: Ni = 2048, Nj = 2048, Nk = 256

Variants	Performance (GFLOPs)
A x B	1858.82
At x B	1918.11
A x Bt	1892.31
At x Bt	1718.58

Test Case 4: Ni = 1024, Nj = 1024, Nk = 1024

Variants	Performance (GFLOPs)
A x B	1882.17
At x B	1939.95
A x Bt	1931.91
At x Bt	1715.02

Test Case 5: Ni = 256, Nj = 256, Nk = 16,384

Variants	Performance (GFLOPs)
A x B	940.20
At x B	940.20
A x Bt	940.20
At x Bt	857.96

Test Case 6: Ni = 64, Nj = 64, Nk = 262,144

Variants	Performance (GFLOPs)
A x B	278.30
At x B	209.01
A x Bt	226.27
At x Bt	170.28

Test Case 7: Ni = 16, Nj = 16, Nk = 4,194,304

Variants	Performance (GFLOPs)
A x B	31.39
At x B	25.71
A x Bt	26.23
At x Bt	20.62

Test Case 8: Ni = 8,991, Nj = 8,991, Nk = 37

Variants	Performance (GFLOPs)
A x B	366.17
At x B	371.78
A x Bt	384.09
At x Bt	384.01

Test Case 9: Ni = 2,997, Nj = 2,997, Nk = 11

Variants	Performance (GFLOPs)
A x B	508.05
At x B	513.08
A x Bt	512.21
At x Bt	514.79

Test Case 10: Ni = 999, Nj = 999, Nk = 999

Variants	Performance (GFLOPs)
A x B	495.00
At x B	502.98
A x Bt	494.56
At x Bt	510.39

Test Case 11: Ni = 333, Nj = 333, Nk = 8,991

Variants	Performance (GFLOPs)
A x B	466.09
At x B	398.64
A x Bt	385.36
At x Bt	391.51

Test Case 12: Ni = 111, Nj = 111, Nk = 80,919

Variants	Performance (GFLOPs)
A x B	301.18
At x B	303.00
A x Bt	312.28
At x Bt	331.36

Test Case 13: Ni = 37, Nj = 37, Nk = 728,271

Variants	Performance (GFLOPs)
A x B	137.60
At x B	127.91
A x Bt	127.35
At x Bt	112.12

1.2 Lonepeak Performance - TODO Awaiting on JOB Results

Test Case 1: Ni = 8,192, Nj = 8,192, Nk = 16

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 2: Ni = 4096, Nj = 4096, Nk = 64

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 3: Ni = 2048, Nj = 2048, Nk = 256

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 4: Ni = 1024, Nj = 1024, Nk = 1024

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 5: Ni = 256, Nj = 256, Nk = 16,384

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 6: Ni = 64, Nj = 64, Nk = 262,144

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 7: Ni = 16, Nj = 16, Nk = 4,194,304

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 8: Ni = 8,991, Nj = 8,991, Nk = 37

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 9: Ni = 2,997, Nj = 2,997, Nk = 11

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 10: Ni = 999, Nj = 999, Nk = 999

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 11: Ni = 333, Nj = 333, Nk = 8,991

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 12: Ni = 111, Nj = 111, Nk = 80,919

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Test Case 13: Ni = 37, Nj = 37, Nk = 728,271

Variants	Performance (GFLOPs)
A x B	
At x B	
A x Bt	
At x Bt	

Apendix

1. OpenMP CADE Lab Output

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Matrix dimension Ni: 8192, Nj 8192, Nk: 16
Max Threads (from omp_get_max_threads) = 16

A x B    Reference sequential performance for AB (in GFLOPS) Min: 3.33; Max: 3.41
        Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 16.77 92.04 115.82 || 5.03 27.62 34.76
        Worst Performance (GFLOPS || Speedup): 16.74 91.14 114.46 || 4.91 26.72 33.55

At x B   Reference sequential performance for ATB (in GFLOPS) Min: 2.47; Max: 2.48
        Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 16.48 92.06 115.25 || 6.68 37.30 46.69
        Worst Performance (GFLOPS || Speedup): 15.77 89.89 113.99 || 6.37 36.30 46.03

A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 5.90; Max: 5.90
        Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 16.91 95.06 116.50 || 2.87 16.12 19.75
        Worst Performance (GFLOPS || Speedup): 16.74 89.83 114.80 || 2.84 15.22 19.45

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 3.49; Max: 3.51
        Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 16.89 84.65 115.55 || 4.84 24.25 33.10
        Worst Performance (GFLOPS || Speedup): 16.49 83.66 108.54 || 4.70 23.81 30.90
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Matrix dimension Ni: 4096, Nj 4096, Nk: 64
Max Threads (from omp_get_max_threads) = 16

A x B    Reference sequential performance for AB (in GFLOPS) Min: 1.79; Max: 1.80
        Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 18.04 106.60 151.04 || 10.06 59.47 84.26
        Worst Performance (GFLOPS || Speedup): 18.03 105.51 149.60 || 10.03 58.71 83.25

At x B   Reference sequential performance for ATB (in GFLOPS) Min: 1.31; Max: 1.35
        Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 17.99 105.46 149.09 || 13.72 80.43 113.70
        Worst Performance (GFLOPS || Speedup): 17.96 105.23 146.43 || 13.26 77.67 108.09

A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 3.95; Max: 3.95
        Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 18.01 106.16 150.06 || 4.56 26.87 37.97
        Worst Performance (GFLOPS || Speedup): 17.87 105.14 146.90 || 4.52 26.59 37.15

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 1.83; Max: 1.83
        Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 18.00 105.68 148.55 || 9.84 57.80 81.24
        Worst Performance (GFLOPS || Speedup): 17.77 104.40 147.13 || 9.71 57.05 80.40
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Matrix dimension Ni: 2048, Nj 2048, Nk: 256
Max Threads (from omp_get_max_threads) = 16
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A x B Reference sequential performance for AB (in GFLOPS) Min: 1.57; Max: 1.64
Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
Best Performance (GFLOPS || Speedup): 18.83 107.41 156.02 || 12.03 68.62 99.67
Worst Performance (GFLOPS || Speedup): 18.68 105.76 154.45 || 11.41 64.57 94.30

At x B Reference sequential performance for ATB (in GFLOPS) Min: 0.85; Max: 0.92
Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
Best Performance (GFLOPS || Speedup): 19.21 106.33 153.43 || 22.70 125.65 181.31
Worst Performance (GFLOPS || Speedup): 18.80 105.02 149.74 || 20.38 113.83 162.29

A x Bt Reference sequential performance for ABT (in GFLOPS) Min: 2.80; Max: 2.85
Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
Best Performance (GFLOPS || Speedup): 19.26 106.39 153.58 || 6.89 38.03 54.91
Worst Performance (GFLOPS || Speedup): 19.17 105.88 147.04 || 6.73 37.14 51.58

At x Bt Reference sequential performance for ATBT (in GFLOPS) Min: 1.60; Max: 1.60
Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
Best Performance (GFLOPS || Speedup): 19.04 104.71 149.81 || 11.90 65.42 93.60
Worst Performance (GFLOPS || Speedup): 17.54 103.11 147.76 || 10.95 64.36 92.23

Matrix dimension Ni: 1024, Nj 1024, Nk: 1024
Max Threads (from omp_get_max_threads) = 16

A x B Reference sequential performance for AB (in GFLOPS) Min: 1.60; Max: 1.61
Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
Best Performance (GFLOPS || Speedup): 19.57 101.41 151.71 || 12.19 63.20 94.55
Worst Performance (GFLOPS || Speedup): 19.32 100.08 146.54 || 12.02 62.24 91.13

At x B Reference sequential performance for ATB (in GFLOPS) Min: 0.88; Max: 0.89
Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
Best Performance (GFLOPS || Speedup): 19.34 99.00 139.84 || 21.94 112.32 158.65
Worst Performance (GFLOPS || Speedup): 18.93 97.72 134.73 || 21.35 110.18 151.92

A x Bt Reference sequential performance for ABT (in GFLOPS) Min: 2.46; Max: 2.47
Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
Best Performance (GFLOPS || Speedup): 19.18 99.08 140.23 || 7.79 40.22 56.92
Worst Performance (GFLOPS || Speedup): 19.03 96.27 131.52 || 7.71 39.01 53.30

At x Bt Reference sequential performance for ATBT (in GFLOPS) Min: 1.46; Max: 1.57
Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
Best Performance (GFLOPS || Speedup): 18.97 94.12 128.75 || 13.01 64.57 88.33
Worst Performance (GFLOPS || Speedup): 18.80 92.35 123.61 || 11.99 58.91 78.85

Matrix dimension Ni: 256, Nj 256, Nk: 16384
Max Threads (from omp_get_max_threads) = 16

A x B Reference sequential performance for AB (in GFLOPS) Min: 0.87; Max: 0.87
Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
Best Performance (GFLOPS || Speedup): 13.63 86.21 116.80 || 15.70 99.29 134.53
Worst Performance (GFLOPS || Speedup): 13.37 83.48 115.48 || 15.37 95.99 132.78

At x B Reference sequential performance for ATB (in GFLOPS) Min: 0.37; Max: 0.38
Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
Best Performance (GFLOPS || Speedup): 12.99 75.36 94.12 || 34.88 202.32 252.70
Worst Performance (GFLOPS || Speedup): 12.89 66.79 93.27 || 33.58 173.95 242.88

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A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 2.32; Max: 2.34
        Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 13.39 78.17 99.68 || 5.77 33.67 42.93
        Worst Performance (GFLOPS || Speedup): 12.44 77.31 99.04 || 5.33 33.11 42.41

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 1.01; Max: 1.04
        Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 12.94 68.39 83.24 || 12.80 67.66 82.35
        Worst Performance (GFLOPS || Speedup): 12.42 50.45 82.40 || 11.95 48.54 79.29
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Matrix dimension Ni: 64, Nj 64, Nk: 262144
Max Threads (from omp_get_max_threads) = 16

A x B    Reference sequential performance for AB (in GFLOPS) Min: 0.40; Max: 0.41
        Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 7.67 44.99 75.42 || 19.16 112.35 188.34
        Worst Performance (GFLOPS || Speedup): 7.67 44.45 74.96 || 18.63 108.05 182.20

At x B   Reference sequential performance for ATB (in GFLOPS) Min: 0.16; Max: 0.16
        Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 6.69 34.49 44.55 || 42.39 218.35 282.05
        Worst Performance (GFLOPS || Speedup): 6.67 33.99 44.07 || 41.90 213.61 276.94

A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 2.26; Max: 2.27
        Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 6.87 36.01 53.60 || 3.04 15.95 23.73
        Worst Performance (GFLOPS || Speedup): 6.81 35.72 53.15 || 3.00 15.71 23.38

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 0.43; Max: 0.43
        Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 6.24 29.03 38.24 || 14.64 68.11 89.73
        Worst Performance (GFLOPS || Speedup): 6.23 28.58 35.34 || 14.51 66.56 82.29
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Matrix dimension Ni: 16, Nj 16, Nk: 4194304
Max Threads (from omp_get_max_threads) = 16

A x B    Reference sequential performance for AB (in GFLOPS) Min: 0.70; Max: 0.72
        Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 8.60 28.46 27.61 || 12.28 40.64 39.41
        Worst Performance (GFLOPS || Speedup): 8.58 23.65 24.63 || 11.91 32.83 34.20

At x B   Reference sequential performance for ATB (in GFLOPS) Min: 0.32; Max: 0.32
        Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 6.64 16.74 16.79 || 20.78 52.43 52.59
        Worst Performance (GFLOPS || Speedup): 6.62 15.70 16.09 || 20.69 49.06 50.26

A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 2.18; Max: 2.19
        Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 6.27 15.53 20.25 || 2.87 7.11 9.27
        Worst Performance (GFLOPS || Speedup): 6.18 13.32 17.13 || 2.83 6.09 7.83

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 0.71; Max: 0.72
        Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 4.60 14.49 15.54 || 6.49 20.45 21.92
        Worst Performance (GFLOPS || Speedup): 4.59 13.35 13.62 || 6.37 18.53 18.89
```

```
Matrix dimension Ni: 8991, Nj 8991, Nk: 37
Max Threads (from omp_get_max_threads) = 16

A x B    Reference sequential performance for AB (in GFLOPS) Min: 3.65; Max: 3.68
       Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
       Best Performance  (GFLOPS || Speedup): 18.08 113.19 154.00 || 4.95 30.98 42.15
       Worst Performance (GFLOPS || Speedup): 17.94 112.69 153.58 || 4.87 30.60 41.70

At x B   Reference sequential performance for ATB (in GFLOPS) Min: 3.28; Max: 3.30
       Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
       Best Performance  (GFLOPS || Speedup): 18.27 113.06 153.67 || 5.56 34.43 46.79
       Worst Performance (GFLOPS || Speedup): 18.24 112.23 153.04 || 5.53 34.03 46.41

A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 4.79; Max: 4.80
       Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
       Best Performance  (GFLOPS || Speedup): 18.23 113.06 154.66 || 3.80 23.59 32.27
       Worst Performance (GFLOPS || Speedup): 18.20 112.64 152.22 || 3.79 23.47 31.72

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 3.57; Max: 3.68
       Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
       Best Performance  (GFLOPS || Speedup): 17.97 112.62 153.26 || 5.04 31.59 42.99
       Worst Performance (GFLOPS || Speedup): 17.88 111.89 151.78 || 4.86 30.42 41.27
```

```
Matrix dimension Ni: 2997, Nj 2997, Nk: 111
Max Threads (from omp_get_max_threads) = 16

A x B    Reference sequential performance for AB (in GFLOPS) Min: 2.71; Max: 2.72
       Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
       Best Performance  (GFLOPS || Speedup): 18.72 118.48 162.81 || 6.90 43.66 60.00
       Worst Performance (GFLOPS || Speedup): 18.25 114.56 78.41 || 6.71 42.11 28.82

At x B   Reference sequential performance for ATB (in GFLOPS) Min: 2.49; Max: 2.54
       Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
       Best Performance  (GFLOPS || Speedup): 18.70 118.43 162.82 || 7.50 47.51 65.32
       Worst Performance (GFLOPS || Speedup): 18.43 106.61 156.45 || 7.26 42.00 61.63

A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 3.68; Max: 3.70
       Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
       Best Performance  (GFLOPS || Speedup): 18.70 118.27 161.71 || 5.09 32.18 44.00
       Worst Performance (GFLOPS || Speedup): 18.49 116.90 160.36 || 5.00 31.59 43.34

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 2.92; Max: 2.93
       Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
       Best Performance  (GFLOPS || Speedup): 18.54 117.23 160.02 || 6.35 40.13 54.77
       Worst Performance (GFLOPS || Speedup): 18.29 114.75 156.99 || 6.24 39.12 53.52
```

```
Matrix dimension Ni: 999, Nj 999, Nk: 999
Max Threads (from omp_get_max_threads) = 16

A x B    Reference sequential performance for AB (in GFLOPS) Min: 2.31; Max: 2.32
       Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
       Best Performance  (GFLOPS || Speedup): 18.88 113.40 149.65 || 8.17 49.09 64.78
       Worst Performance (GFLOPS || Speedup): 18.86 111.59 146.67 || 8.14 48.16 63.30

At x B   Reference sequential performance for ATB (in GFLOPS) Min: 1.42; Max: 1.42
       Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
       Best Performance  (GFLOPS || Speedup): 18.57 110.53 138.33 || 13.10 77.98 97.59
```

```
        Worst Performance (GFLOPS || Speedup): 18.48 98.13 135.31 || 13.02 69.15 95.35

A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 2.44; Max: 2.44
        Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 18.57 110.59 138.35 || 7.61 45.31 56.69
        Worst Performance (GFLOPS || Speedup): 18.49 109.95 136.47 || 7.57 45.01 55.87

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 2.31; Max: 2.32
        Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 18.29 107.25 130.56 || 7.92 46.44 56.53
        Worst Performance (GFLOPS || Speedup): 17.99 105.78 124.50 || 7.74 45.50 53.56
_____________________________________________________________________________________

Matrix dimension Ni: 333, Nj 333, Nk: 8991
Max Threads (from omp_get_max_threads) = 16

A x B    Reference sequential performance for AB (in GFLOPS) Min: 1.47; Max: 1.51
        Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 17.39 90.10 127.90 || 11.83 61.28 86.99
        Worst Performance (GFLOPS || Speedup): 17.37 88.90 124.20 || 11.47 58.70 82.00

At x B   Reference sequential performance for ATB (in GFLOPS) Min: 0.78; Max: 0.79
        Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 16.58 81.56 108.62 || 21.30 104.81 139.59
        Worst Performance (GFLOPS || Speedup): 16.50 80.56 104.45 || 21.01 102.57 132.97

A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 2.30; Max: 2.35
        Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 16.84 83.56 110.52 || 7.33 36.40 48.14
        Worst Performance (GFLOPS || Speedup): 16.31 81.70 106.11 || 6.94 34.75 45.13

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 1.44; Max: 1.44
        Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 16.08 76.57 93.98 || 11.16 53.14 65.22
        Worst Performance (GFLOPS || Speedup): 15.83 75.42 88.41 || 10.96 52.21 61.20
_____________________________________________________________________________________

Matrix dimension Ni: 111, Nj 111, Nk: 80919
Max Threads (from omp_get_max_threads) = 16

A x B    Reference sequential performance for AB (in GFLOPS) Min: 1.04; Max: 1.04
        Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 8.13 50.81 89.64 || 7.82 48.87 86.21
        Worst Performance (GFLOPS || Speedup): 7.99 50.53 88.94 || 7.66 48.47 85.32

At x B   Reference sequential performance for ATB (in GFLOPS) Min: 0.55; Max: 0.55
        Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 6.90 34.63 54.52 || 12.53 62.90 99.02
        Worst Performance (GFLOPS || Speedup): 6.87 34.45 52.60 || 12.39 62.16 94.90

A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 2.28; Max: 2.28
        Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 7.86 46.22 74.65 || 3.45 20.30 32.79
        Worst Performance (GFLOPS || Speedup): 7.83 45.64 74.01 || 3.43 20.03 32.48

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 0.99; Max: 1.05
        Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
        Best Performance  (GFLOPS || Speedup): 7.02 32.41 47.69 || 7.06 32.58 47.94
        Worst Performance (GFLOPS || Speedup): 6.79 32.17 46.39 || 6.49 30.75 44.34
```

```
Matrix dimension Ni: 37, Nj 37, Nk: 728271
Max Threads (from omp_get_max_threads) = 16

A x B    Reference sequential performance for AB (in GFLOPS) Min: 0.43; Max: 0.44
         Performance of parallel version for AB (in GFLOPS) 1/7/15 using threads
         Best Performance  (GFLOPS || Speedup): 7.77 41.92 70.45 || 17.95 96.82 162.74
         Worst Performance (GFLOPS || Speedup): 7.74 38.62 66.22 || 17.69 88.27 151.34

At x B   Reference sequential performance for ATB (in GFLOPS) Min: 0.20; Max: 0.20
         Performance of parallel version for ATB (in GFLOPS) 1/7/15 using threads
         Best Performance  (GFLOPS || Speedup): 5.03 25.86 40.67 || 25.12 129.24 203.26
         Worst Performance (GFLOPS || Speedup): 4.92 25.71 36.71 || 24.34 127.31 181.74

A x Bt   Reference sequential performance for ABT (in GFLOPS) Min: 2.25; Max: 2.29
         Performance of parallel version for ABT (in GFLOPS) 1/7/15 using threads
         Best Performance  (GFLOPS || Speedup): 7.28 33.68 46.03 || 3.23 14.95 20.43
         Worst Performance (GFLOPS || Speedup): 7.19 33.29 45.77 || 3.14 14.52 19.96

At x Bt  Reference sequential performance for ATBT (in GFLOPS) Min: 0.45; Max: 0.46
         Performance of parallel version for ATBT (in GFLOPS) 1/7/15 using threads
         Best Performance  (GFLOPS || Speedup): 4.93 22.43 30.92 || 11.01 50.11 69.08
         Worst Performance (GFLOPS || Speedup): 4.91 22.35 30.77 || 10.68 48.59 66.90
```

2. OpenMP CADE Lonepeak Output Pending

3. CUDA CADE Lab Output

```
Matrix dimension Ni: 8192, Nj 8192, Nk: 16

Trial 0: AB GFLOPS: 335.41
Trial 1: AB GFLOPS: 798.12
Trial 2: AB GFLOPS: 798.48

Trial 0: ATB GFLOPS: 769.13
Trial 1: ATB GFLOPS: 791.14
Trial 2: ATB GFLOPS: 801.63

Trial 0: ABT GFLOPS: 819.16
Trial 1: ABT GFLOPS: 845.40
Trial 2: ABT GFLOPS: 846.51

Trial 0: ATBT GFLOPS: 813.59
Trial 1: ATBT GFLOPS: 840.82
Trial 2: ATBT GFLOPS: 840.31
```

```
Matrix dimension Ni: 4096, Nj 4096, Nk: 64
```

Trial 0: AB GFLOPS: 809.19
Trial 1: AB GFLOPS: 1767.98
Trial 2: AB GFLOPS: 1750.96

Trial 0: ATB GFLOPS: 1740.78
Trial 1: ATB GFLOPS: 1857.79
Trial 2: ATB GFLOPS: 1863.15

Trial 0: ABT GFLOPS: 1682.52
Trial 1: ABT GFLOPS: 1782.96
Trial 2: ABT GFLOPS: 1788.23

Trial 0: ATBT GFLOPS: 1529.30
Trial 1: ATBT GFLOPS: 1677.93
Trial 2: ATBT GFLOPS: 1672.41

Matrix dimension Ni: 2048, Nj 2048, Nk: 256

Trial 0: AB GFLOPS: 953.21
Trial 1: AB GFLOPS: 1867.82
Trial 2: AB GFLOPS: 1858.82

Trial 0: ATB GFLOPS: 1782.77
Trial 1: ATB GFLOPS: 1921.84
Trial 2: ATB GFLOPS: 1918.11

Trial 0: ABT GFLOPS: 1721.93
Trial 1: ABT GFLOPS: 1888.32
Trial 2: ABT GFLOPS: 1892.31

Trial 0: ATBT GFLOPS: 1554.63
Trial 1: ATBT GFLOPS: 1719.11
Trial 2: ATBT GFLOPS: 1718.58

Matrix dimension Ni: 1024, Nj 1024, Nk: 1024

Trial 0: AB GFLOPS: 648.77
Trial 1: AB GFLOPS: 1799.07
Trial 2: AB GFLOPS: 1882.17

Trial 0: ATB GFLOPS: 1748.40
Trial 1: ATB GFLOPS: 1934.75
Trial 2: ATB GFLOPS: 1939.95

Trial 0: ABT GFLOPS: 1742.59
Trial 1: ABT GFLOPS: 1840.16
Trial 2: ABT GFLOPS: 1931.91

Trial 0: ATBT GFLOPS: 1619.70
Trial 1: ATBT GFLOPS: 1714.72
Trial 2: ATBT GFLOPS: 1715.02

Matrix dimension Ni: 256, Nj 256, Nk: 16384

Trial 0: AB GFLOPS: 475.47

Trial 1: AB GFLOPS: 949.09
Trial 2: AB GFLOPS: 940.20

Trial 0: ATB GFLOPS: 909.70
Trial 1: ATB GFLOPS: 953.25
Trial 2: ATB GFLOPS: 950.71

Trial 0: ABT GFLOPS: 889.94
Trial 1: ABT GFLOPS: 930.92
Trial 2: ABT GFLOPS: 931.33

Trial 0: ATBT GFLOPS: 830.41
Trial 1: ATBT GFLOPS: 858.51
Trial 2: ATBT GFLOPS: 857.96

Matrix dimension Ni: 64, Nj 64, Nk: 262144

Trial 0: AB GFLOPS: 231.10
Trial 1: AB GFLOPS: 278.73
Trial 2: AB GFLOPS: 278.30

Trial 0: ATB GFLOPS: 206.43
Trial 1: ATB GFLOPS: 208.99
Trial 2: ATB GFLOPS: 209.01

Trial 0: ABT GFLOPS: 226.52
Trial 1: ABT GFLOPS: 226.00
Trial 2: ABT GFLOPS: 226.27

Trial 0: ATBT GFLOPS: 166.59
Trial 1: ATBT GFLOPS: 167.86
Trial 2: ATBT GFLOPS: 170.28

Matrix dimension Ni: 16, Nj 16, Nk: 4194304

Trial 0: AB GFLOPS: 28.63
Trial 1: AB GFLOPS: 30.29
Trial 2: AB GFLOPS: 31.39

Trial 0: ATB GFLOPS: 25.68
Trial 1: ATB GFLOPS: 25.72
Trial 2: ATB GFLOPS: 25.71

Trial 0: ABT GFLOPS: 26.21
Trial 1: ABT GFLOPS: 26.23
Trial 2: ABT GFLOPS: 26.23

Trial 0: ATBT GFLOPS: 20.60
Trial 1: ATBT GFLOPS: 20.62
Trial 2: ATBT GFLOPS: 20.62

Matrix dimension Ni: 8991, Nj 8991, Nk: 37

Trial 0: AB GFLOPS: 331.36
Trial 1: AB GFLOPS: 366.10
Trial 2: AB GFLOPS: 366.17

Trial 0: ATB GFLOPS: 369.31
Trial 1: ATB GFLOPS: 371.80
Trial 2: ATB GFLOPS: 371.78

Trial 0: ABT GFLOPS: 382.02
Trial 1: ABT GFLOPS: 383.86
Trial 2: ABT GFLOPS: 384.09

Trial 0: ATBT GFLOPS: 382.29
Trial 1: ATBT GFLOPS: 384.00
Trial 2: ATBT GFLOPS: 384.01

Matrix dimension Ni: 2997, Nj 2997, Nk: 111

Trial 0: AB GFLOPS: 321.33
Trial 1: AB GFLOPS: 507.61
Trial 2: AB GFLOPS: 508.05

Trial 0: ATB GFLOPS: 501.84
Trial 1: ATB GFLOPS: 513.10
Trial 2: ATB GFLOPS: 513.08

Trial 0: ABT GFLOPS: 502.10
Trial 1: ABT GFLOPS: 512.01
Trial 2: ABT GFLOPS: 512.21

Trial 0: ATBT GFLOPS: 505.61
Trial 1: ATBT GFLOPS: 514.85
Trial 2: ATBT GFLOPS: 514.79

Matrix dimension Ni: 999, Nj 999, Nk: 999

Trial 0: AB GFLOPS: 258.24
Trial 1: AB GFLOPS: 496.28
Trial 2: AB GFLOPS: 495.00

Trial 0: ATB GFLOPS: 493.68
Trial 1: ATB GFLOPS: 503.05
Trial 2: ATB GFLOPS: 502.98

Trial 0: ABT GFLOPS: 487.18
Trial 1: ABT GFLOPS: 494.74
Trial 2: ABT GFLOPS: 494.56

Trial 0: ATBT GFLOPS: 500.80
Trial 1: ATBT GFLOPS: 508.72
Trial 2: ATBT GFLOPS: 510.39

Matrix dimension Ni: 333, Nj 333, Nk: 8991

Trial 0: AB GFLOPS: 52.10
Trial 1: AB GFLOPS: 472.88
Trial 2: AB GFLOPS: 466.09

Trial 0: ATB GFLOPS: 391.54

Trial 1: ATB GFLOPS: 384.30
Trial 2: ATB GFLOPS: 398.64

Trial 0: ABT GFLOPS: 386.31
Trial 1: ABT GFLOPS: 392.61
Trial 2: ABT GFLOPS: 385.36

Trial 0: ATBT GFLOPS: 386.17
Trial 1: ATBT GFLOPS: 391.95
Trial 2: ATBT GFLOPS: 391.51

Matrix dimension Ni: 111, Nj 111, Nk: 80919

Trial 0: AB GFLOPS: 240.45
Trial 1: AB GFLOPS: 298.68
Trial 2: AB GFLOPS: 301.18

Trial 0: ATB GFLOPS: 309.02
Trial 1: ATB GFLOPS: 311.93
Trial 2: ATB GFLOPS: 303.00

Trial 0: ABT GFLOPS: 307.72
Trial 1: ABT GFLOPS: 312.63
Trial 2: ABT GFLOPS: 312.28

Trial 0: ATBT GFLOPS: 327.60
Trial 1: ATBT GFLOPS: 331.70
Trial 2: ATBT GFLOPS: 331.36

Matrix dimension Ni: 37, Nj 37, Nk: 728271

Trial 0: AB GFLOPS: 78.85
Trial 1: AB GFLOPS: 137.74
Trial 2: AB GFLOPS: 137.60

Trial 0: ATB GFLOPS: 127.02
Trial 1: ATB GFLOPS: 128.66
Trial 2: ATB GFLOPS: 127.91

Trial 0: ABT GFLOPS: 126.59
Trial 1: ABT GFLOPS: 126.68
Trial 2: ABT GFLOPS: 127.35

Trial 0: ATBT GFLOPS: 111.51
Trial 1: ATBT GFLOPS: 112.73
Trial 2: ATBT GFLOPS: 112.12

4. CUDA CADE Lonepeak Output Pending