Requirement#2 Parallel Computing

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Matrix Addition

A. kernel1: each thread produces one output **matrix element**

1. No. of Rows **=** No. of Cols
    a. 1 Block

```
==10428== NVPROF is profiling process 10428, command: ./kernel4
==10428== Profiling application: ./kernel4
==10428== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   64.95%  6.2967ms         1  6.2967ms  6.2967ms  6.2967ms  [CUDA memcpy DtoH]
                   35.01%  3.3944ms         2  1.6972ms  1.6547ms  1.7396ms  [CUDA memcpy HtoD]
                    0.04%  4.3200us         1  4.3200us  4.3200us  4.3200us  MatAdd(double*, double*, double*, int, int)
      API calls:   94.03%  218.14ms         3  72.712ms  122.13us  217.87ms  cudaMalloc
                    5.33%  12.376ms         3  4.1252ms  1.8651ms  8.5204ms  cudaMemcpy
                    0.43%  1.0023ms         3  334.09us  168.15us  423.06us  cudaFree
                    0.11%  249.94us         1  249.94us  249.94us  249.94us  cudaLaunchKernel
                    0.08%  191.06us       114  1.6750us     174ns  74.767us  cuDeviceGetAttribute
                    0.01%  15.187us         1  15.187us  15.187us  15.187us  cuDeviceGetName
                    0.00%  8.2000us         1  8.2000us  8.2000us  8.2000us  cuDeviceGetPCIBusId
                    0.00%  6.0100us         1  6.0100us  6.0100us  6.0100us  cuDeviceTotalMem
                    0.00%  2.8390us         3     946ns     353ns  2.1210us  cuDeviceGetCount
                    0.00%  1.4830us         2     741ns     275ns  1.2080us  cuDeviceGet
                    0.00%     695ns         1     695ns     695ns     695ns  cuModuleGetLoadingMode
                    0.00%     444ns         1     444ns     444ns     444ns  cuDeviceGetUuid
./kernel4
```

    b. Multiple Blocks

```
!nvcc /tmp/tmptt345pl9/6afaa60c-c10f-4bbd-9671-502c2177804c/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==10182== NVPROF is profiling process 10182, command: ./kernel4
./kernel4==10182== Profiling application: ./kernel4
==10182== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   60.21%  5.0349ms         1  5.0349ms  5.0349ms  5.0349ms  [CUDA memcpy DtoH]
                   38.70%  3.2365ms         2  1.6183ms  1.5652ms  1.6713ms  [CUDA memcpy HtoD]
                    1.09%  90.976us         1  90.976us  90.976us  90.976us  MatAdd(double*, double*, double*, int, int)
      API calls:   94.72%  202.58ms         3  67.527ms  85.036us  202.40ms  cudaMalloc
                    4.67%  9.9843ms         3  3.3281ms  1.7723ms  6.3148ms  cudaMemcpy
                    0.41%  886.87us         3  295.62us  120.96us  392.97us  cudaFree
                    0.10%  223.45us         1  223.45us  223.45us  223.45us  cudaLaunchKernel
                    0.07%  155.49us       114  1.3630us     172ns  61.778us  cuDeviceGetAttribute
                    0.01%  13.654us         1  13.654us  13.654us  13.654us  cuDeviceGetName
                    0.00%  9.3630us         1  9.3630us  9.3630us  9.3630us  cuDeviceGetPCIBusId
                    0.00%  4.9610us         1  4.9610us  4.9610us  4.9610us  cuDeviceTotalMem
                    0.00%  2.0940us         3     698ns     232ns  1.5050us  cuDeviceGetCount
                    0.00%  1.1230us         2     561ns     197ns     926ns  cuDeviceGet
                    0.00%     697ns         1     697ns     697ns     697ns  cuModuleGetLoadingMode
                    0.00%     282ns         1     282ns     282ns     282ns  cuDeviceGetUuid
```

2. No. of Rows **>** No. of Cols
    a. 1 Block

```
] !nvcc /tmp/tmpkx_yfdy6/8fa4e71e-661e-48c1-9b36-c0a155ea085a/single_file.cu -o kernel4
  !nvprof ./kernel4
```

```
==1317== NVPROF is profiling process 1317, command: ./kernel4
==1317== Profiling application: ./kernel4
./kernel4==1317== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   59.77%  18.112us         2  9.0560us  8.9280us  9.1840us  [CUDA memcpy HtoD]
                   27.88%  8.4480us         1  8.4480us  8.4480us  8.4480us  [CUDA memcpy DtoH]
                   12.35%  3.7430us         1  3.7430us  3.7430us  3.7430us  MatAdd(double*, double*, double*, int, int)
      API calls:   99.68%  187.87ms         3  62.622ms  4.6550us  187.86ms  cudaMalloc
                    0.10%  182.24us         1  182.24us  182.24us  182.24us  cudaLaunchKernel
                    0.09%  166.03us         3  55.343us  33.410us  93.038us  cudaMemcpy
                    0.07%  131.20us       114  1.1500us     137ns  51.857us  cuDeviceGetAttribute
                    0.05%  98.983us         3  32.994us  4.1300us  87.626us  cudaFree
                    0.01%  10.372us         1  10.372us  10.372us  10.372us  cuDeviceGetName
                    0.00%  8.4540us         1  8.4540us  8.4540us  8.4540us  cuDeviceGetPCIBusId
                    0.00%  4.4700us         1  4.4700us  4.4700us  4.4700us  cuDeviceTotalMem
                    0.00%  1.6020us         3     534ns     185ns     970ns  cuDeviceGetCount
                    0.00%     918ns         2     459ns     173ns     745ns  cuDeviceGet
                    0.00%     429ns         1     429ns     429ns     429ns  cuModuleGetLoadingMode
                    0.00%     214ns         1     214ns     214ns     214ns  cuDeviceGetUuid
```

b. Multiple Blocks

```
/tmp/tmpkx_yfdy6/200820f0-4a81-4fd7-a6aa-386d09079c6d/cuda_exec.out
```

```
✓ 1s  !nvcc /tmp/tmpkx_yfdy6/200820f0-4a81-4fd7-a6aa-386d09079c6d/single_file.cu -o kernel4
      !nvprof ./kernel4
```

```
==2085== NVPROF is profiling process 2085, command: ./kernel4
./kernel4==2085== Profiling application: ./kernel4
==2085== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   61.43%  19.167us         2  9.5830us  9.4390us  9.7280us  [CUDA memcpy HtoD]
                   26.98%  8.4160us         1  8.4160us  8.4160us  8.4160us  [CUDA memcpy DtoH]
                   11.59%  3.6160us         1  3.6160us  3.6160us  3.6160us  MatAdd(double*, double*, double*, int, int)
      API calls:   99.66%  193.65ms         3  64.551ms  4.5520us  193.64ms  cudaMalloc
                    0.09%  181.35us         1  181.35us  181.35us  181.35us  cudaLaunchKernel
                    0.09%  177.38us       114  1.5550us     143ns  63.952us  cuDeviceGetAttribute
                    0.08%  162.96us         3  54.321us  23.395us  84.664us  cudaMemcpy
                    0.05%  104.43us         3  34.810us  3.7660us  93.305us  cudaFree
                    0.01%  11.524us         1  11.524us  11.524us  11.524us  cuDeviceGetName
                    0.00%  5.5070us         1  5.5070us  5.5070us  5.5070us  cuDeviceGetPCIBusId
                    0.00%  5.3930us         1  5.3930us  5.3930us  5.3930us  cuDeviceTotalMem
                    0.00%  2.7580us         2  1.3790us     237ns  2.5210us  cuDeviceGet
                    0.00%  1.6440us         3     548ns     199ns  1.1630us  cuDeviceGetCount
                    0.00%     669ns         1     669ns     669ns     669ns  cuModuleGetLoadingMode
                    0.00%     242ns         1     242ns     242ns     242ns  cuDeviceGetUuid
```

3. No. of Rows < No. of Cols
    a. 1 Block

```
!nvcc /tmp/tmpkx_yfdy6/94a27c60-285c-466e-a17c-b24ea8da0043/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==1724== NVPROF is profiling process 1724, command: ./kernel4
==1724== Profiling application: ./kernel4
==1724== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   60.13%  18.624us         2  9.3120us  9.1840us  9.4400us  [CUDA memcpy HtoD]
                   28.20%  8.7360us         1  8.7360us  8.7360us  8.7360us  [CUDA memcpy DtoH]
                   11.67%  3.6150us         1  3.6150us  3.6150us  3.6150us  MatAdd(double*, double*, double*, int, int)
      API calls:   99.65%  215.75ms         3  71.916ms  6.1840us  215.74ms  cudaMalloc
                    0.09%  205.66us         1  205.66us  205.66us  205.66us  cudaLaunchKernel
                    0.09%  205.44us       114  1.8020us     216ns  68.624us  cuDeviceGetAttribute
                    0.09%  184.72us         3  61.574us  40.605us  98.640us  cudaMemcpy
                    0.06%  131.80us         3  43.933us  5.6290us  116.22us  cudaFree
                    0.01%  12.125us         1  12.125us  12.125us  12.125us  cuDeviceGetName
                    0.00%  7.3590us         1  7.3590us  7.3590us  7.3590us  cuDeviceGetPCIBusId
                    0.00%  6.3670us         1  6.3670us  6.3670us  6.3670us  cuDeviceTotalMem
                    0.00%  2.0270us         3     675ns     317ns  1.3880us  cuDeviceGetCount
                    0.00%  1.0510us         2     525ns     315ns     736ns  cuDeviceGet
                    0.00%     494ns         1     494ns     494ns     494ns  cuDeviceGetUuid
                    0.00%     434ns         1     434ns     434ns     434ns  cuModuleGetLoadingMode
./kernel4
```

    b. Multiple Blocks

```
!nvcc /tmp/tmpkx_yfdy6/71a7165e-68b1-4728-98eb-312d30f1ac19/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==2333== NVPROF is profiling process 2333, command: ./kernel4
./kernel4==2333== Profiling application: ./kernel4
==2333== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   59.65%  18.495us         2  9.2470us  8.9910us  9.5040us  [CUDA memcpy HtoD]
                   29.00%  8.9910us         1  8.9910us  8.9910us  8.9910us  [CUDA memcpy DtoH]
                   11.35%  3.5200us         1  3.5200us  3.5200us  3.5200us  MatAdd(double*, double*, double*, int, int)
      API calls:   99.70%  202.91ms         3  67.636ms  3.0350us  202.90ms  cudaMalloc
                    0.09%  182.84us         1  182.84us  182.84us  182.84us  cudaLaunchKernel
                    0.08%  160.94us         3  53.645us  35.604us  84.271us  cudaMemcpy
                    0.06%  129.53us       114  1.1360us     145ns  51.667us  cuDeviceGetAttribute
                    0.06%  113.67us         3  37.891us  3.8790us  101.94us  cudaFree
                    0.01%  10.830us         1  10.830us  10.830us  10.830us  cuDeviceGetName
                    0.00%  5.0690us         1  5.0690us  5.0690us  5.0690us  cuDeviceGetPCIBusId
                    0.00%  3.9410us         1  3.9410us  3.9410us  3.9410us  cuDeviceTotalMem
                    0.00%  1.3760us         3     458ns     190ns     921ns  cuDeviceGetCount
                    0.00%     908ns         2     454ns     203ns     705ns  cuDeviceGet
                    0.00%     590ns         1     590ns     590ns     590ns  cuModuleGetLoadingMode
                    0.00%     202ns         1     202ns     202ns     202ns  cuDeviceGetUuid
```

B. kernel2: each thread produces one output **matrix row**

1. No. of Rows **=** No. of Cols
    a. 1 Block

```
!nvcc /tmp/tmptt345pl9/bc0d086d-a42d-4935-885d-8a7fffb82547/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==9290== NVPROF is profiling process 9290, command: ./kernel4
./kernel4==9290== Profiling application: ./kernel4
==9290== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   60.01%  6.7077ms         1  6.7077ms  6.7077ms  6.7077ms  [CUDA memcpy DtoH]
                   31.02%  3.4673ms         2  1.7336ms  1.7112ms  1.7561ms  [CUDA memcpy HtoD]
                    8.97%  1.0021ms         1  1.0021ms  1.0021ms  1.0021ms  MatAdd(double*, double*, double*, int, int)
      API calls:   94.08%  235.03ms         3  78.344ms  115.47us  234.78ms  cudaMalloc
                    5.29%  13.205ms         3  4.4015ms  1.9718ms  9.2415ms  cudaMemcpy
                    0.41%  1.0306ms         3  343.52us  167.08us  431.89us  cudaFree
                    0.13%  313.22us         1  313.22us  313.22us  313.22us  cudaLaunchKernel
                    0.08%  207.17us       114  1.8170us     183ns  79.395us  cuDeviceGetAttribute
                    0.01%  16.612us         1  16.612us  16.612us  16.612us  cuDeviceGetName
                    0.00%  8.3550us         1  8.3550us  8.3550us  8.3550us  cuDeviceGetPCIBusId
                    0.00%  6.8670us         1  6.8670us  6.8670us  6.8670us  cuDeviceTotalMem
                    0.00%  2.6130us         3     871ns     327ns  1.8920us  cuDeviceGetCount
                    0.00%  1.8530us         2     926ns     306ns  1.5470us  cuDeviceGet
                    0.00%     703ns         1     703ns     703ns     703ns  cuModuleGetLoadingMode
                    0.00%     483ns         1     483ns     483ns     483ns  cuDeviceGetUuid
```

    b. Multiple Blocks

```
!nvcc /tmp/tmptt345pl9/97a828b2-eed9-4f63-820a-0e8ab4e8ffee/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==8958== NVPROF is profiling process 8958, command: ./kernel4
./kernel4==8958== Profiling application: ./kernel4
==8958== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   95.60%  179.36ms         1  179.36ms  179.36ms  179.36ms  MatAdd(double*, double*, double*, int, int)
                    2.69%  5.0404ms         1  5.0404ms  5.0404ms  5.0404ms  [CUDA memcpy DtoH]
                    1.71%  3.2099ms         2  1.6050ms  1.5689ms  1.6410ms  [CUDA memcpy HtoD]
      API calls:   50.90%  197.52ms         3  65.840ms  87.873us  197.34ms  cudaMalloc
                   48.79%  189.31ms         3  63.104ms  1.8173ms  185.64ms  cudaMemcpy
                    0.20%  764.86us         3  254.95us  201.93us  291.44us  cudaFree
                    0.07%  273.48us         1  273.48us  273.48us  273.48us  cudaLaunchKernel
                    0.04%  138.80us       114  1.2170us     144ns  55.778us  cuDeviceGetAttribute
                    0.00%  12.032us         1  12.032us  12.032us  12.032us  cuDeviceGetName
                    0.00%  6.0110us         1  6.0110us  6.0110us  6.0110us  cuDeviceGetPCIBusId
                    0.00%  4.1910us         1  4.1910us  4.1910us  4.1910us  cuDeviceTotalMem
                    0.00%  1.7510us         3     583ns     216ns  1.2380us  cuDeviceGetCount
                    0.00%  1.1310us         2     565ns     266ns     865ns  cuDeviceGet
                    0.00%     530ns         1     530ns     530ns     530ns  cuModuleGetLoadingMode
                    0.00%     240ns         1     240ns     240ns     240ns  cuDeviceGetUuid
```

2. No. of Rows **>** No. of Cols
    a. 1 Block

```
==2951== NVPROF is profiling process 2951, command: ./kernel4
./kernel4==2951== Profiling application: ./kernel4
==2951== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   53.44%  18.655us         2  9.3270us  9.2150us  9.4400us  [CUDA memcpy HtoD]
                   23.92%  8.3520us         1  8.3520us  8.3520us  8.3520us  [CUDA memcpy DtoH]
                   22.64%  7.9040us         1  7.9040us  7.9040us  7.9040us  MatAdd(double*, double*, double*, int, int)
      API calls:   99.62%  191.30ms         3  63.765ms  4.6510us  191.29ms  cudaMalloc
                    0.13%  241.63us         1  241.63us  241.63us  241.63us  cudaLaunchKernel
                    0.09%  168.05us       114  1.4740us     136ns  88.322us  cuDeviceGetAttribute
                    0.09%  166.59us         3  55.531us  34.234us  90.515us  cudaMemcpy
                    0.07%  136.84us         3  45.614us  4.1850us  125.50us  cudaFree
                    0.01%  11.497us         1  11.497us  11.497us  11.497us  cuDeviceGetName
                    0.00%  4.9800us         1  4.9800us  4.9800us  4.9800us  cuDeviceGetPCIBusId
                    0.00%  4.2910us         1  4.2910us  4.2910us  4.2910us  cuDeviceTotalMem
                    0.00%  1.5340us         3     511ns     187ns  1.0610us  cuDeviceGetCount
                    0.00%     888ns         2     444ns     184ns     704ns  cuDeviceGet
                    0.00%     585ns         1     585ns     585ns     585ns  cuModuleGetLoadingMode
                    0.00%     222ns         1     222ns     222ns     222ns  cuDeviceGetUuid
```

    b. Multiple Blocks

```
!nvcc /tmp/tmpkx_yfdy6/7fbdc249-8183-4a84-a011-d4153f21e0b1/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==3391== NVPROF is profiling process 3391, command: ./kernel4
./kernel4==3391== Profiling application: ./kernel4
==3391== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   41.56%  18.976us         2  9.4880us  9.2160us  9.7600us  [CUDA memcpy HtoD]
                   40.43%  18.463us         1  18.463us  18.463us  18.463us  MatAdd(double*, double*, double*, int, int)
                   18.01%  8.2240us         1  8.2240us  8.2240us  8.2240us  [CUDA memcpy DtoH]
      API calls:   99.65%  187.85ms         3  62.617ms  5.0890us  187.84ms  cudaMalloc
                    0.10%  194.41us         1  194.41us  194.41us  194.41us  cudaLaunchKernel
                    0.10%  189.24us         3  63.080us  39.547us  95.084us  cudaMemcpy
                    0.08%  142.66us       114  1.2510us     136ns  51.208us  cuDeviceGetAttribute
                    0.05%  102.96us         3  34.318us  3.9950us  91.520us  cudaFree
                    0.01%  10.542us         1  10.542us  10.542us  10.542us  cuDeviceGetName
                    0.00%  5.1660us         1  5.1660us  5.1660us  5.1660us  cuDeviceTotalMem
                    0.00%  5.1010us         1  5.1010us  5.1010us  5.1010us  cuDeviceGetPCIBusId
                    0.00%  1.5080us         3     502ns     181ns  1.0370us  cuDeviceGetCount
                    0.00%     947ns         2     473ns     180ns     767ns  cuDeviceGet
                    0.00%     447ns         1     447ns     447ns     447ns  cuModuleGetLoadingMode
                    0.00%     310ns         1     310ns     310ns     310ns  cuDeviceGetUuid
```

```
[ ]
```

3. No. of Rows < No. of Cols
    a. 1 Block

```
!nvcc /tmp/tmpkx_yfdy6/8d08a9fb-a6c7-491a-a824-f36a42e61eec/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==3159== NVPROF is profiling process 3159, command: ./kernel4
./kernel4==3159== Profiling application: ./kernel4
==3159== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   96.04%  642.55us         1  642.55us  642.55us  642.55us  MatAdd(double*, double*, double*, int, int)
                    2.72%  18.207us         2  9.1030us  8.8320us  9.3750us  [CUDA memcpy HtoD]
                    1.23%  8.2560us         1  8.2560us  8.2560us  8.2560us  [CUDA memcpy DtoH]
      API calls:   99.33%  193.97ms         3  64.655ms  4.7880us  193.95ms  cudaMalloc
                    0.41%  799.89us         3  266.63us  34.531us  723.50us  cudaMemcpy
                    0.12%  229.52us         1  229.52us  229.52us  229.52us  cudaLaunchKernel
                    0.07%  138.71us       114  1.2160us     137ns  52.360us  cuDeviceGetAttribute
                    0.06%  110.66us         3  36.885us  3.9440us  99.102us  cudaFree
                    0.01%  12.730us         1  12.730us  12.730us  12.730us  cuDeviceGetName
                    0.00%  6.4380us         1  6.4380us  6.4380us  6.4380us  cuDeviceGetPCIBusId
                    0.00%  4.8880us         1  4.8880us  4.8880us  4.8880us  cuDeviceTotalMem
                    0.00%  1.6970us         3     565ns     198ns  1.2430us  cuDeviceGetCount
                    0.00%     977ns         2     488ns     212ns     765ns  cuDeviceGet
                    0.00%     453ns         1     453ns     453ns     453ns  cuModuleGetLoadingMode
                    0.00%     344ns         1     344ns     344ns     344ns  cuDeviceGetUuid
```

    b. Multiple Blocks

```
==3635== NVPROF is profiling process 3635, command: ./kernel4
==3635== Profiling application: ./kernel4
==3635== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   98.87%  2.3706ms         1  2.3706ms  2.3706ms  2.3706ms  MatAdd(double*, double*, double*, int, int)
                    0.78%  18.815us         2  9.4070us  9.0870us  9.7280us  [CUDA memcpy HtoD]
                    0.34%  8.1930us         1  8.1930us  8.1930us  8.1930us  [CUDA memcpy DtoH]
      API calls:   98.56%  214.85ms         3  71.617ms  6.8190us  214.84ms  cudaMalloc
                    1.17%  2.5452ms         3  848.41us  34.500us  2.4644ms  cudaMemcpy
                    0.11%  246.18us         1  246.18us  246.18us  246.18us  cudaLaunchKernel
                    0.09%  185.69us       114  1.6280us     169ns  72.205us  cuDeviceGetAttribute
                    0.06%  141.16us         3  47.054us  5.6000us  123.70us  cudaFree
                    0.01%  13.621us         1  13.621us  13.621us  13.621us  cuDeviceGetName
                    0.00%  7.2120us         1  7.2120us  7.2120us  7.2120us  cuDeviceGetPCIBusId
                    0.00%  5.5570us         1  5.5570us  5.5570us  5.5570us  cuDeviceTotalMem
                    0.00%  2.5990us         3     866ns     390ns  1.7700us  cuDeviceGetCount
                    0.00%  1.2170us         2     608ns     283ns     934ns  cuDeviceGet
                    0.00%     600ns         1     600ns     600ns     600ns  cuModuleGetLoadingMode
                    0.00%     469ns         1     469ns     469ns     469ns  cuDeviceGetUuid
./kernel4
```

C. kernel3: each thread produces one output **matrix column**

1. No. of Rows **=** No. of Cols
    a. 1 Block

```
!nvcc /tmp/tmptt345pl9/8aab4501-ce45-439b-9d7d-354d569e81a2/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==9578== NVPROF is profiling process 9578, command: ./kernel4
./kernel4==9578== Profiling application: ./kernel4
==9578== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   59.04%  4.8906ms         1  4.8906ms  4.8906ms  4.8906ms  [CUDA memcpy DtoH]
                   37.43%  3.1009ms         2  1.5505ms  1.5368ms  1.5642ms  [CUDA memcpy HtoD]
                    3.53%  292.48us         1  292.48us  292.48us  292.48us  MatAdd(double*, double*, double*, int, int)
      API calls:   94.62%  196.96ms         3  65.653ms  88.528us  196.77ms  cudaMalloc
                    4.75%  9.8919ms         3  3.2973ms  1.7302ms  6.3646ms  cudaMemcpy
                    0.43%  897.62us         3  299.21us  135.15us  386.72us  cudaFree
                    0.12%  243.95us         1  243.95us  243.95us  243.95us  cudaLaunchKernel
                    0.07%  146.62us       114  1.2860us     135ns  62.590us  cuDeviceGetAttribute
                    0.01%  12.689us         1  12.689us  12.689us  12.689us  cuDeviceGetName
                    0.00%  5.6700us         1  5.6700us  5.6700us  5.6700us  cuDeviceGetPCIBusId
                    0.00%  4.8150us         1  4.8150us  4.8150us  4.8150us  cuDeviceTotalMem
                    0.00%  2.5550us         2  1.2770us     181ns  2.3740us  cuDeviceGet
                    0.00%  2.3800us         3     793ns     218ns  1.8930us  cuDeviceGetCount
                    0.00%     590ns         1     590ns     590ns     590ns  cuModuleGetLoadingMode
                    0.00%     225ns         1     225ns     225ns     225ns  cuDeviceGetUuid
```

    b. Multiple Blocks

```
!nvcc /tmp/tmptt345pl9/8da52388-949a-44ec-8975-35075674ee63/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==9838== NVPROF is profiling process 9838, command: ./kernel4
./kernel4==9838== Profiling application: ./kernel4
==9838== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   69.17%  25.801ms         1  25.801ms  25.801ms  25.801ms  MatAdd(double*, double*, double*, int, int)
                   16.77%  6.2543ms         1  6.2543ms  6.2543ms  6.2543ms  [CUDA memcpy DtoH]
                   14.06%  5.2444ms         2  2.6222ms  1.7101ms  3.5343ms  [CUDA memcpy HtoD]
      API calls:   84.86%  228.49ms         3  76.162ms  144.51us  228.19ms  cudaMalloc
                   14.56%  39.192ms         3  13.064ms  1.9295ms  33.474ms  cudaMemcpy
                    0.38%  1.0195ms         3  339.82us  213.81us  411.59us  cudaFree
                    0.11%  302.60us         1  302.60us  302.60us  302.60us  cudaLaunchKernel
                    0.07%  201.36us       114  1.7660us     217ns  77.343us  cuDeviceGetAttribute
                    0.01%  15.587us         1  15.587us  15.587us  15.587us  cuDeviceGetName
                    0.00%  7.9340us         1  7.9340us  7.9340us  7.9340us  cuDeviceGetPCIBusId
                    0.00%  5.7540us         1  5.7540us  5.7540us  5.7540us  cuDeviceTotalMem
                    0.00%  2.3510us         3     783ns     310ns  1.6350us  cuDeviceGetCount
                    0.00%  1.4860us         2     743ns     273ns  1.2130us  cuDeviceGet
                    0.00%     512ns         1     512ns     512ns     512ns  cuModuleGetLoadingMode
                    0.00%     449ns         1     449ns     449ns     449ns  cuDeviceGetUuid
```

2. No. of Rows **>** No. of Cols
    a. 1 Block

```
!nvcc /tmp/tmpkx_yfdy6/d1e07eb9-34bd-49c5-b18e-96e25c1eccae/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==3987== NVPROF is profiling process 3987, command: ./kernel4
./kernel4==3987== Profiling application: ./kernel4
==3987== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   89.99%  240.28us         1  240.28us  240.28us  240.28us  MatAdd(double*, double*, double*, int, int)
                    6.93%  18.496us         2  9.2480us  8.9920us  9.5040us  [CUDA memcpy HtoD]
                    3.08%  8.2240us         1  8.2240us  8.2240us  8.2240us  [CUDA memcpy DtoH]
      API calls:   99.53%  183.04ms         3  61.014ms  4.7150us  183.03ms  cudaMalloc
                    0.21%  390.57us         3  130.19us  34.723us  316.64us  cudaMemcpy
                    0.12%  212.13us         1  212.13us  212.13us  212.13us  cudaLaunchKernel
                    0.07%  131.18us       114  1.1500us     140ns  51.902us  cuDeviceGetAttribute
                    0.06%  103.47us         3  34.488us  4.2090us  90.776us  cudaFree
                    0.01%  10.763us         1  10.763us  10.763us  10.763us  cuDeviceGetName
                    0.01%  9.8020us         1  9.8020us  9.8020us  9.8020us  cuDeviceTotalMem
                    0.00%  5.2260us         1  5.2260us  5.2260us  5.2260us  cuDeviceGetPCIBusId
                    0.00%  1.5470us         3     515ns     184ns  1.0800us  cuDeviceGetCount
                    0.00%  1.0840us         2     542ns     236ns     848ns  cuDeviceGet
                    0.00%     568ns         1     568ns     568ns     568ns  cuModuleGetLoadingMode
                    0.00%     213ns         1     213ns     213ns     213ns  cuDeviceGetUuid
```

    b. Multiple Blocks

```
!nvprof ./kernel4
```

```
==4531== NVPROF is profiling process 4531, command: ./kernel4
./kernel4==4531== Profiling application: ./kernel4
==4531== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   92.84%  351.23us         1  351.23us  351.23us  351.23us  MatAdd(double*, double*, double*, int, int)
                    4.98%  18.847us         2  9.4230us  9.1510us  9.6960us  [CUDA memcpy HtoD]
                    2.17%  8.2240us         1  8.2240us  8.2240us  8.2240us  [CUDA memcpy DtoH]
      API calls:   99.50%  194.22ms         3  64.740ms  4.6650us  194.21ms  cudaMalloc
                    0.27%  518.20us         3  172.73us  34.674us  442.23us  cudaMemcpy
                    0.10%  198.03us         1  198.03us  198.03us  198.03us  cudaLaunchKernel
                    0.07%  131.50us       114  1.1530us     148ns  52.444us  cuDeviceGetAttribute
                    0.06%  108.04us         3  36.014us  4.1300us  95.985us  cudaFree
                    0.01%  11.820us         1  11.820us  11.820us  11.820us  cuDeviceGetName
                    0.00%  5.2310us         1  5.2310us  5.2310us  5.2310us  cuDeviceGetPCIBusId
                    0.00%  4.4400us         1  4.4400us  4.4400us  4.4400us  cuDeviceTotalMem
                    0.00%  1.7540us         3     584ns     167ns  1.2790us  cuDeviceGetCount
                    0.00%  1.0560us         2     528ns     234ns     822ns  cuDeviceGet
                    0.00%     613ns         1     613ns     613ns     613ns  cuModuleGetLoadingMode
                    0.00%     212ns         1     212ns     212ns     212ns  cuDeviceGetUuid
```

3. No. of Rows < No. of Cols
    a. 1 Block

```
!nvcc /tmp/tmpkx_yfdy6/ee23a084-9841-4b20-9921-cd586e8d270f/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==4279== NVPROF is profiling process 4279, command: ./kernel4
==4279== Profiling application: ./kernel4
==4279== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   53.88%  18.431us         2  9.2150us  9.1510us  9.2800us  [CUDA memcpy HtoD]
                   24.32%  8.3200us         1  8.3200us  8.3200us  8.3200us  [CUDA memcpy DtoH]
                   21.80%  7.4560us         1  7.4560us  7.4560us  7.4560us  MatAdd(double*, double*, double*, int, int)
      API calls:   99.62%  221.21ms         3  73.737ms  7.1960us  221.20ms  cudaMalloc
                    0.12%  273.45us         1  273.45us  273.45us  273.45us  cudaLaunchKernel
                    0.09%  197.44us       114  1.7310us     277ns  78.500us  cuDeviceGetAttribute
                    0.09%  195.25us         3  65.082us  35.142us  110.09us  cudaMemcpy
                    0.07%  148.82us         3  49.605us  6.3400us  131.70us  cudaFree
                    0.01%  13.113us         1  13.113us  13.113us  13.113us  cuDeviceGetName
                    0.00%  8.0080us         1  8.0080us  8.0080us  8.0080us  cuDeviceGetPCIBusId
                    0.00%  6.1750us         1  6.1750us  6.1750us  6.1750us  cuDeviceTotalMem
                    0.00%  2.2550us         3     751ns     368ns  1.5080us  cuDeviceGetCount
                    0.00%  1.0930us         2     546ns     337ns     756ns  cuDeviceGet
                    0.00%     563ns         1     563ns     563ns     563ns  cuDeviceGetUuid
                    0.00%     498ns         1     498ns     498ns     498ns  cuModuleGetLoadingMode
./kernel4
```

    b. Multiple Blocks

```
!nvcc /tmp/tmpkx_yfdy6/095be174-05ef-481c-b778-afc100c08854/single_file.cu -o kernel4
!nvprof ./kernel4
```

```
==4755== NVPROF is profiling process 4755, command: ./kernel4
./kernel4==4755== Profiling application: ./kernel4
==4755== Profiling result:
            Type  Time(%)      Time     Calls       Avg       Min       Max  Name
 GPU activities:   51.29%  18.496us         2  9.2480us  8.8960us  9.6000us  [CUDA memcpy HtoD]
                   25.91%  9.3440us         1  9.3440us  9.3440us  9.3440us  MatAdd(double*, double*, double*, int, int)
                   22.80%  8.2230us         1  8.2230us  8.2230us  8.2230us  [CUDA memcpy DtoH]
      API calls:   99.65%  196.26ms         3  65.419ms  3.3720us  196.25ms  cudaMalloc
                    0.11%  225.32us         1  225.32us  225.32us  225.32us  cudaLaunchKernel
                    0.09%  170.57us         3  56.857us  37.462us  92.463us  cudaMemcpy
                    0.07%  133.05us       114  1.1670us     144ns  52.931us  cuDeviceGetAttribute
                    0.07%  129.32us         3  43.107us  4.3070us  117.10us  cudaFree
                    0.01%  13.216us         1  13.216us  13.216us  13.216us  cuDeviceTotalMem
                    0.01%  11.906us         1  11.906us  11.906us  11.906us  cuDeviceGetName
                    0.00%  5.0270us         1  5.0270us  5.0270us  5.0270us  cuDeviceGetPCIBusId
                    0.00%  1.5450us         3     515ns     223ns  1.0510us  cuDeviceGetCount
                    0.00%  1.0770us         2     538ns     192ns     885ns  cuDeviceGet
                    0.00%     435ns         1     435ns     435ns     435ns  cuModuleGetLoadingMode
                    0.00%     218ns         1     218ns     218ns     218ns  cuDeviceGetUuid
```

Summary

A. kernel1: each thread produces one output **matrix element**

	1 Block	**Multiple Blocks**
No. of Rows **=** No. of Cols = 1000	**4.32 us**	**90.976 us**
No. of Rows(1000) **>** No. of Cols(10)	**3.743 us**	**3.616 us**
No. of Rows(10) **<** No. of Cols(1000)	**3.615 us**	**3.52 us**

Comments:

1- When the No. of Rows **=** the No. of Cols, it is clear that using 1 block for calculation is better than using multiple blocks as threads within one block can communicate to each other but threads from different blocks can not communicate to each other so using multiple blocks is slower as we need to wait till all blocks finished the calculations (**Using one block reduced the synchronization overhead**).

2- When No. of Rows(1000) **>** No. of Cols(10) or No. of Rows(10) **<** No. of Cols(1000), we notice that there is no a big difference in time either using one block or multiple blocks. This lack of significant difference occurs because the dimension with fewer elements will dominate the computational workload, and the synchronization overhead associated with multiple blocks becomes less relevant.

B. kernel2: each thread produces one output **matrix row**

	1 Block	**Multiple Blocks**
No. of Rows **=** No. of Cols = 1000	**1.0021 ms**	**179.36 ms**
No. of Rows(1000) **>** No. of Cols(10)	**7.904 us**	**18.463 us**
No. of Rows(10) **<** No. of Cols(1000)	**642.55 us**	**2.37 ms**

Comments:

1- When the No. of Rows **=** the No. of Cols, it is clear that using 1 block for calculation is better than using multiple blocks as threads within one block can communicate to each other but threads from different blocks can not communicate to each other so using multiple blocks is slower as we need to wait till all blocks finished the calculations (**Using one block reduced the synchronization overhead**).

2- When No. of Rows(1000) **>** No. of Cols(10) and each thread will compute a row so the number of threads = number of rows = 1000 thread and it is fine to calculate the sum in efficient time as number of threads will be large.

3- When No. of Rows(10) **<** No. of Cols(1000) and each thread will compute a row so the number of threads = number of rows = 10 thread and it is not fine to calculate the sum in efficient time as number of threads will be small.In addition to each thread have large number of elements to compute, so it is clear that when No. of Rows(1000) **>** No. of Cols(10) is better then when No. of Rows(10) **<** No. of Cols(1000) as each thread will compute a row so the number of threads = number of rows.

C. kernel3: each thread produces one output **matrix column**

	1 Block	**Multiple Blocks**
No. of Rows **=** No. of Cols = 1000	**292.48 us**	**25.8 ms**
No. of Rows(1000) **>** No. of Cols(10)	**240.28 us**	**351.23 us**
No. of Rows(10) **<** No. of Cols(1000)	**7.456 us**	**9.344 us**

Comments:

1- When the No. of Rows **=** the No. of Cols, it is clear that using 1 block for calculation is better than using multiple blocks as threads within one block can communicate to each other but threads from different blocks can not communicate to each other so using multiple blocks is slower as we need to wait till all blocks finished the calculations (**Using one block reduced the synchronization overhead**).

2- When No. of Rows(10) **<** No. of Cols(1000) and each thread will compute a column so the number of threads = number of cols = 1000 thread and it is fine to calculate the sum in efficient time as number of threads will be large.

3- When No. of Rows(1000) **>** No. of Cols(10) and each thread will compute a column so the number of threads = number of columns = 10 thread and it is not fine to calculate the sum in efficient time as number of threads will be small.In addition to each thread have large number of elements to compute, so it is clear that when No. of Rows(10) **<** No. of Cols(1000) is better then when No. of Rows(1000) **>** No. of Cols(10) as each thread will compute a column so the number of threads = number of cols.