Project Milestone 1-3 Report

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Milestone 1

1. A List of all Kernels that Collectively Consume More than 90% of the Program Time:

Time(%)	Time(ms)	Name
34.00	118.46	void fermiPlusCgemmLDS128_batched<...>
26.94	93.879	void cudnn::detail::implicit_convolve_sgemm<...>
12.65	44.060	void fft2d_c2r_32x32<...>
8.19	28.540	sgemm_sm35_ldg_tn_128x8x256x16x32
6.65	23.153	[CUDA memcpy HtoD]
4.06	14.157	void cudnn::detail::activation_fw_4d_kernel<...>
3.81	13.289	void cudnn::detail::pooling_fw_4d_kernel<...>
1.71	5.9454	void fft2d_r2c_32x32<...>
1.16	4.0542	sgemm_sm35_ldg_tn_64x16x128x8x32

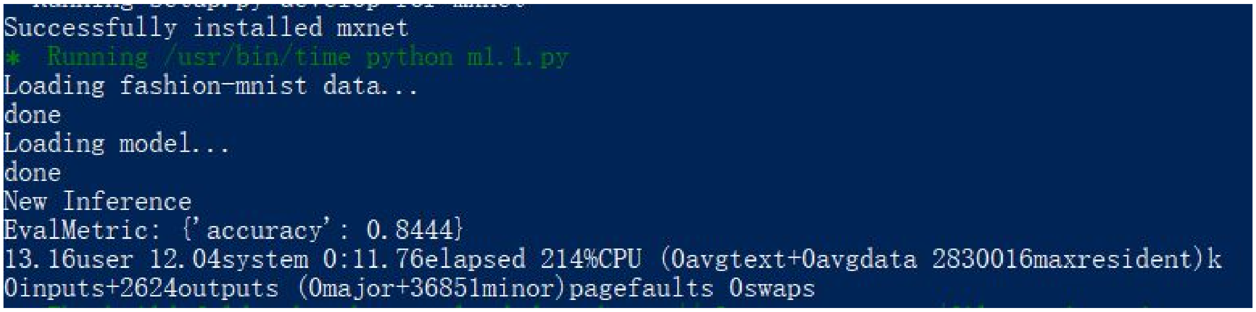
2. A list of all CUDA API calls that collectively consume more than 90% of the program time:

Time(%)	Time(ms)	Name
43.48	1.92	cudaStreamCreateWithFlags
27.11	1.20	cudaFree
20.71	916.54	cudaMemGetInfo
7.31	323.45	cudaStreamSynchronize
1.08	47.75	cudaMemcpy2DAsync
0.16	7.15	cudaMalloc
0.03	1.37	cuDeviceTotalMem

3. Explain the difference between kernels and API calls

Kernels are function launched to be executed on the device while APIs are used to communicate between different software components.

4. Show Output of rai Running MXNet on the CPU:



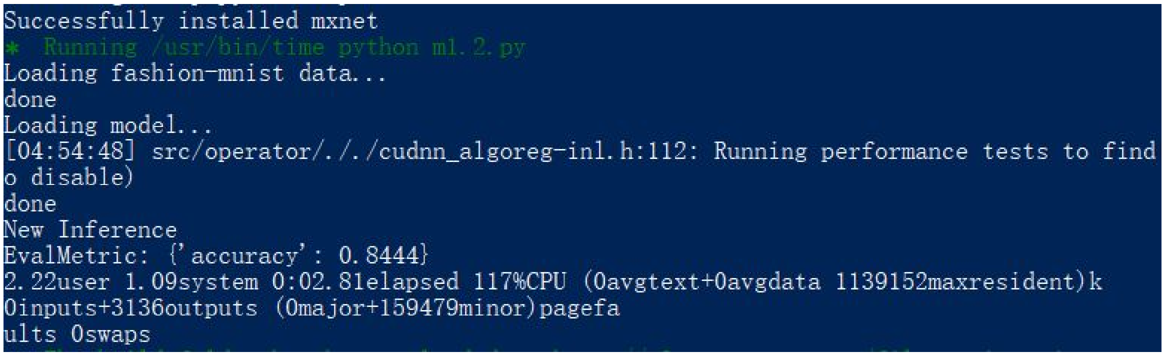
```
Successfully installed mxnet
*  Running /usr/bin/time python m1.1.py
Loading fashion-mnist data...
done
Loading model...
done
New Inference
EvalMetric: {'accuracy': 0.8444}
13.16user 12.04system 0:11.76elapsed 214%CPU (0avgtext+0avgdata 2830016maxresident)k
0inputs+2624outputs (0major+36851minor)pagefaults 0swaps
```

Figure: the snapshot of the result we have by running MXNet on the CPU

5. Program Run-Time (CPU):

From the result shown in the PowerShell, we can tell the run-time on the CPU is 11.76 seconds.

6. Show Output of rai Running MXNet on the GPU:



```
Successfully installed mxnet
*  Running /usr/bin/time python m1.2.py
Loading fashion-mnist data...
done
Loading model...
[04:54:48] src/operator/./cudnn_algoreg-inl.h:112: Running performance tests to find
o disable)
done
New Inference
EvalMetric: {'accuracy': 0.8444}
2.22user 1.09system 0:02.81elapsed 117%CPU (0avgtext+0avgdata 1139152maxresident)k
0inputs+3136outputs (0major+159479minor)pagefa
ults 0swaps
```

Figure: the snapshot of the result we have by running MXNet on the GPU

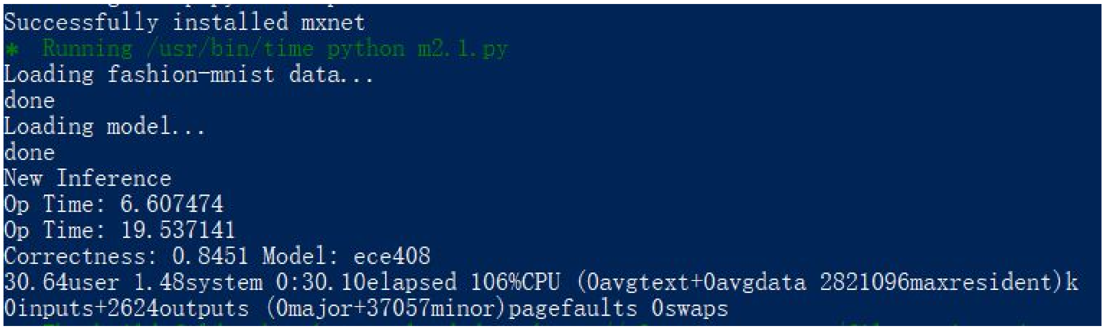
7. Program Run-Time (GPU):

From the result shown in the PowerShell, we can tell the run-time on the GPU is 2.81 seconds.

Milestone 2

1. List whole program execution time:

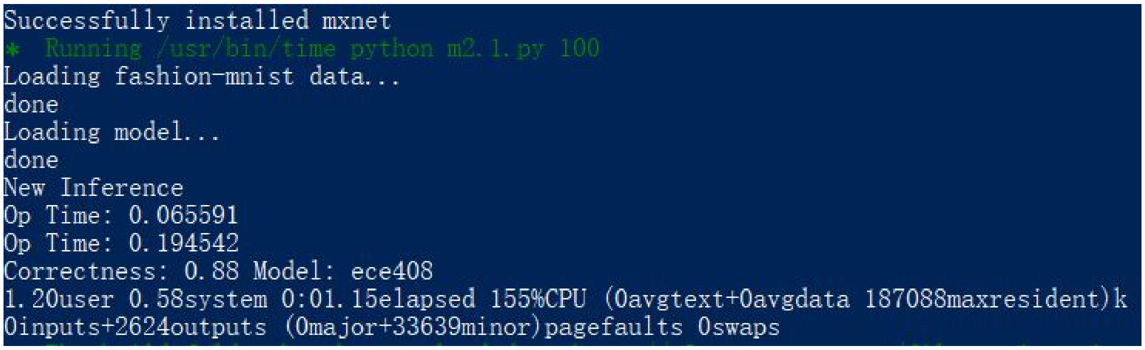
a). 10000 images (default): 30.10 *s*



```
Successfully installed mxnet
*  Running /usr/bin/time python m2.1.py
Loading fashion-mnist data...
done
Loading model...
done
New Inference
Op Time: 6.607474
Op Time: 19.537141
Correctness: 0.8451 Model: ece408
30.64user 1.48system 0:30.10elapsed 106%CPU (0avgtext+0avgdata 2821096maxresident)k
0inputs+2624outputs (0major+37057minor)pagefaults 0swaps
```

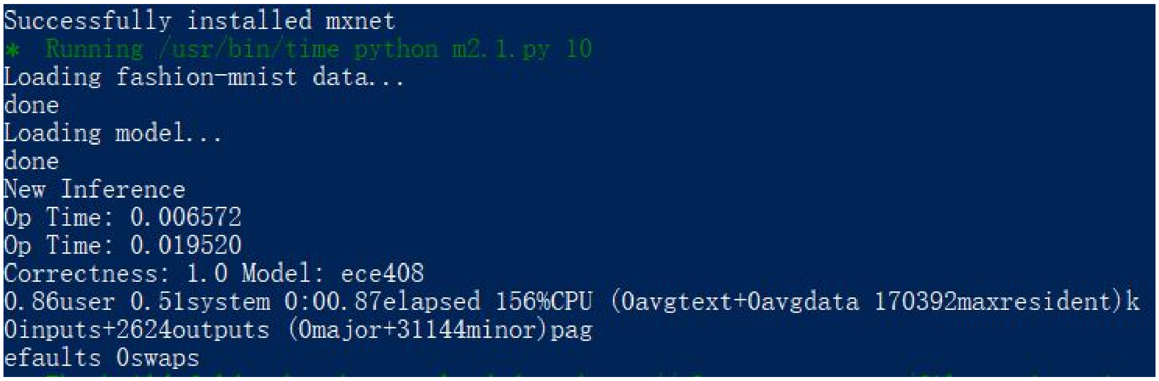
Figure: the snapshot of the result we have by running ConvNet on the CPU with 10000 images

b). 100 images: 1.15 *s*



```
Successfully installed mxnet
*  Running /usr/bin/time python m2.1.py 100
Loading fashion-mnist data...
done
Loading model...
done
New Inference
Op Time: 0.065591
Op Time: 0.194542
Correctness: 0.88 Model: ece408
1.20user 0.58system 0:01.15elapsed 155%CPU (0avgtext+0avgdata 187088maxresident)k
0inputs+2624outputs (0major+33639minor)pagefaults 0swaps
```

Figure: the snapshot of the result we have by running ConvNet on the CPU with 100 images c). 10 images (default): 0.87 *s*



```
Successfully installed mxnet
*  Running /usr/bin/time python m2.1.py 10
Loading fashion-mnist data...
done
Loading model...
done
New Inference
Op Time: 0.006572
Op Time: 0.019520
Correctness: 1.0 Model: ece408
0.86user 0.51system 0:00.87elapsed 156%CPU (0avgtext+0avgdata 170392maxresident)k
0inputs+2624outputs (0major+31144minor)pag
efaults 0swaps
```

Figure: the snapshot of the result we have by running ConvNet on the CPU with 10 images

2. List Op Times:

a). 10000 images (default):

First Layer Op Time:	6.60747 *s*
Second Layer Op Time:	19.537141 *s*

b). 100 images:

First Layer Op Time:	0.065591 *s*
Second Layer Op Time:	0.194542 *s*

c). 10 images:

First Layer Op Time:	0.006572 *s*
Second Layer Op Time:	0.019520 *s*

Milestone 3

1. : nvprof profiling the execution (10000 default data size):

```
✱ Running nvprof python m3.1.py
Loading fashion-mnist data...
done
Loading model...
==314== NVPROF is profiling process 314, command: python m3.1.py
done

New Inference
Op Time: 0.355486
Op Time: 0.652564

Correctness: 0.8451 Model: ece408
==314== Profiling application: python m3.1.py

==314== Profiling result:
```

Time (%)	Time	Calls	Name
89.76	1.00787 s	2	mxnet::op::forward_kernel
2.61	29.329 ms	1	sgemm_sm35_ldg_tn_128x8x256x16x32
2.60	29.224 ms	14	[CUDA memcpy HtoD]
1.96	22.008 ms	2	mshadow::cuda::MapPlanLargeKernel<...>
1.26	14.158 ms	2	cudnn::detail::activation_fw_4d_kernel<...>
1.19	13.310 ms	1	cudnn::detail::pooling_fw_4d_kernel<...>
0.36	4.0730 ms	1	sgemm_sm35_ldg_tn_64x16x128x8x32
0.11	1.2805 ms	1	mshadow::cuda::MapPlanLargeKernel<...>
0.10	1.1112 ms	1	mshadow::cuda::SoftmaxKernel<...>
0.02	177.44 us	13	mshadow::cuda::MapPlanKernel<...>
0.01	146.82 us	2	mshadow::cuda::MapPlanKernel<...>
0.01	129.60 us	1	sgemm_sm35_ldg_tn_32x16x64x8x16
<0.01	23.264 us	1	mshadow::cuda::MapPlanKernel<...>
<0.01	9.6320 us	1	[CUDA memcpy DtoH]

```
==314== API calls:
Time(%)    Time   Call   Avg       Min      Max      Name
 37.07%  2.01992s  18  112.22ms 18.700us 1.00956s    cudaStreamCreateWithFlags
 23.45%  1.27787s  10  127.79ms  1.0610us  359.44ms  cudaFree
 18.90%  1.02999s   6  171.66ms  16.423us  652.50ms  cudaDeviceSynchronize
 18.12%  987.04ms  27  36.557ms  249.68us  978.97ms  cudaMemGetInfo
  1.15%  62.495ms  29  2.1550ms  5.9750us  32.128ms  cudaStreamSynchronize
  1.09%  59.196ms   9  6.5774ms  10.270us  28.498ms  cudaMemcpy2DAsync
  0.12%  6.6691ms  45  148.20us  9.9270us  950.38us  cudaMalloc
  0.03%  1.4217ms   4  355.43us  336.63us  403.41us  cuDeviceTotalMem
  0.02%  1.0917ms 352  3.1010us     512ns  88.433us  cuDeviceGetAttribute
  0.02%  827.59us 114  7.2590us     897ns  305.72us  cudaEventCreateWithFlags
  0.01%  681.04us  28  24.322us  11.212us  67.046us  cudaLaunch
  0.01%  407.12us   6  67.853us  28.668us  137.98us  cudaMemcpy
  0.01%  287.64us   4  71.909us  36.702us  160.69us  cudaStreamCreate
  0.00%  134.58us 168     801ns     522ns  13.878us  cudaSetupArgument
  0.00%  120.73us   4  30.182us  18.224us  36.266us  cuDeviceGetName
  0.00%  96.465us 104     927ns     627ns  2.3410us  cudaDeviceGetAttribute
  0.00%  89.771us  34  2.6400us     925ns  7.5090us  cudaSetDevice
  0.00%  45.847us 2  22.923us  21.098u   24.749 uscudaStreamCreateWithPriority
  0.00%  45.809us  28  1.6360us     779ns  4.3910us  cudaConfigureCall
  0.00%  30.516us  10  3.0510us  1.6350us  7.0540us  cudaGetDevice
  0.00%  17.136us  20     856ns     583ns  1.2970us  cudaPeekAtLastError
  0.00%  7.0090us   6  1.1680us     550ns  2.5230us  cuDeviceGetCount
  0.00%  6.0670us   2  3.0330us  2.5290us  3.5380us  cudaStreamWaitEvent
  0.00%  5.6780us   6     946ns     604ns  1.2170us  cuDeviceGet
  0.00%  5.3790us   2  2.6890us  1.8120us  3.5670us  cudaEventRecord
  0.00%  5.2660us   1  5.2660us  5.2660us  5.2660us  cudaStreamGetPriority
  0.00%  4.7120us   5     942ns     726ns  1.2410us  cudaGetLastError
  0.00%  4.1180us   3  1.3720us  1.2970us  1.4390us  cuInit
  0.00%  3.8380us   2  1.9190us  1.5640us  2.2740us
cudaDeviceGetStreamPriorityRange
  0.00%  3.5850us   3  1.1950us     907ns  1.3690us  cuDriverGetVersion
  0.00%  1.7840us   1  1.7840us  1.7840us  1.7840us  cudaGetDeviceCount
```

2. nvprof profiling the execution (100 data size):

```
✱ Running nvprof python m3.1.py 100
Loading fashion-mnist data...
done
Loading model...
==311== NVPROF is profiling process 311, command: python m3.1.py 100
done

New Inference
Op Time: 0.003272
Op Time: 0.006654

Correctness: 0.88 Model: ece408
==311== Profiling application: python m3.1.py 100
```

```
==311== Profiling result:
```

Time (%)	Time	Calls	Name
78.67	**9.8344 ms**	2	mxnet::op::forward_kernel
9.15	**1.1435 ms**	14	[CUDA memcpy HtoD]
5.45	**680.92 us**	1	sgemm_largek_lds64
2.02	**252.67 us**	2	void mshadow::cuda::MapPlanKernel<...>
1.58	**197.18 us**	14	void mshadow::cuda::MapPlanKernel<...>
1.30	**162.62 us**	2	void cudnn::detail::activation_fw_4d_kernel<...>
1.12	**140.51 us**	1	void cudnn::detail::pooling_fw_4d_kernel<...>
0.33	**41.248 us**	1	sgemm_sm35_ldg_tn_32x16x64x8x16
0.15	**18.239 us**	1	void mshadow::cuda::SoftmaxKernel<...>
0.09	**11.808 us**	1	void mshadow::cuda::MapPlanKernel<...>
0.06	**7.0720 us**	2	void mshadow::cuda::MapPlanKernel<...>
0.04	**4.5760 us**	1	[CUDA memcpy DtoH]
0.03	**3.9680 us**	1	void scal_kernel<...>
0.01	**1.4080 us**	1	[CUDA memset]

```
==311== API calls:
Time(%)    Time  Call   Avg      Min      Max     Name
 47.00%  1.99860s  16  124.91ms  18.774us  999.00ms  cudaStreamCreateWithFlags
 29.76%  1.26567s  10  126.57ms  1.3710us  357.94ms  cudaFree
 22.72%  966.04ms  27  35.779ms  337.00us  957.04ms  cudaMemGetInfo
  0.24%  10.142ms   6  1.6903ms  4.9720us  6.6253ms  cudaDeviceSynchronize
  0.07%  2.8118ms   9  312.43us  10.485us  783.21us  cudaMemcpy2DAsync
  0.07%  2.7961ms  45  62.134us  9.4710us  187.97us  cudaMalloc
  0.04%  1.6533ms  29  57.010us  5.1150us  650.77us  cudaStreamSynchronize
  0.03%  1.3740ms   4  343.51us  341.96us  344.80us  cuDeviceTotalMem
  0.02%  1.0064ms 352  2.8590us     502ns  77.755us  cuDeviceGetAttribute
  0.02%  759.06us 112  6.7770us     866ns  296.13us  cudaEventCreateWithFlags
  0.01%  530.04us  28  18.930us  9.7590us  55.998us  cudaLaunch
  0.01%  463.17us   6  77.195us  26.242us  129.89us  cudaMemcpy
  0.01%  330.98us   4  82.743us  21.216us  228.00us  cudaStreamCreate
  0.00%  125.71us   4  31.426us  22.651us  35.699us  cuDeviceGetName
  0.00%  111.02us 158     702ns     520ns  1.6090us  cudaSetupArgument
  0.00%  99.803us 104     959ns     684ns  2.5010us  cudaDeviceGetAttribute
  0.00%  80.671us  34  2.3720us     801ns  6.8400us  cudaSetDevice
  0.00%  45.615us     2  22.807us  20.577us  25.038us
cudaStreamCreateWithPriority
  0.00%  36.588us    28  1.3060us     655ns  3.9660us  cudaConfigureCall
  0.00%  34.730us     1  34.730us  34.730us  34.730us  cudaMemsetAsync
  0.00%  30.635us    10  3.0630us  1.4260us  6.9790us  cudaGetDevice
  0.00%  15.498us    20     774ns     575ns  1.1170us  cudaPeekAtLastError
  0.00%  8.5720us     8  1.0710us     530ns  2.6530us  cudaGetLastError
  0.00%  7.9230us     1  7.9230us  7.9230us  7.9230us  cudaEventQuery
  0.00%  6.8350us     6  1.1390us     545ns  2.7790us  cuDeviceGetCount
  0.00%  5.0810us     6     846ns     687ns  1.1550us  cuDeviceGet
  0.00%  4.1240us     3  1.3740us  1.3230us  1.4450us  cuInit
  0.00%  3.9170us     2  1.9580us  1.6040us  2.3130us
cudaDeviceGetStreamPriorityRange
  0.00%  2.8320us     1  2.8320us  2.8320us  2.8320us  cudaEventRecord
  0.00%  2.7000us     3     900ns     896ns     907ns  cuDriverGetVersion
  0.00%  1.8210us     1  1.8210us  1.8210us  1.8210us  cudaGetDeviceCount
```

3. nvprof profiling the execution (10 data size):

```
✱ Running nvprof python m3.1.py 10
Loading fashion-mnist data...
done
Loading model...
==314== NVPROF is profiling process 314, command: python m3.1.py 10
done

New Inference
Op Time: 0.000260
Op Time: 0.000733

Correctness: 1.0 Model: ece408

==314== Profiling application: python m3.1.py 10

==314== Profiling result:
```

Time (%)	Time	Calls	Name
38.50	**897.27 us**	2	mxnet::op::forward_kernel
36.27	**845.40 us**	14	[CUDA memcpy HtoD]
10.71	**249.60 us**	1	void sgemm_largek_lds64
7.67	**178.85 us**	14	void mshadow::cuda::MapPlanKernel<...>
1.74	**40.448 us**	1	sgemm_sm35_ldg_tn_32x16x64x8x16
1.37	**31.840 us**	2	void mshadow::cuda::MapPlanKernel

1.11	**25.823 us**	2	void cudnn::detail::activation_fw_4d_kernel<...>
0.81	**18.976 us**	1	void cudnn::detail::pooling_fw_4d_kernel<...>
0.63	**14.720 us**	1	void mshadow::cuda::SoftmaxKernel<...>
0.48	**11.168 us**	1	void mshadow::cuda::MapPlanKernel<...>
0.27	**6.2720 us**	2	void mshadow::cuda::MapPlanKernel<...>
0.20	**4.6400 us**	1	[CUDA memcpy DtoH]
0.18	**4.1280 us**	1	void scal_kernel<...>
0.06	**1.4400 us**	1	[CUDA memset]

```
==314== API calls:
Time(%)    Time  Call   Avg       Min       Max      Name
 47.16%  2.03746s 16  127.34ms  19.098us  1.01841s  cudaStreamCreateWithFlags
 29.59%  1.27843s 10  127.84ms  1.2330us  363.76ms  cudaFree
 22.87%  988.11ms 27  36.597ms  337.32us  979.12ms  cudaMemGetInfo
  0.09%  3.9655ms  4  991.36us  23.032us  3.8549ms  cudaStreamCreate
  0.06%  2.5601ms 45  56.891us  7.8580us  208.19us  cudaMalloc
  0.06%  2.4786ms  9  275.40us  12.252us  758.74us  cudaMemcpy2DAsync
  0.03%  1.3842ms  4  346.06us  340.94us  360.30us  cuDeviceTotalMem
  0.02%  1.0547ms 352  2.9960us    516ns  117.54us  cuDeviceGetAttribute
  0.02%  988.21us  6  164.70us  5.2810us  702.96us  cudaDeviceSynchronize
  0.02%  935.43us 29  32.256us  5.7630us  218.72us  cudaStreamSynchronize
  0.02%  859.79us 112 7.6760us     930ns  294.14us  cudaEventCreateWithFlags
  0.01%  538.01us 28  19.214us  9.2970us  58.700us  cudaLaunch
  0.01%  477.63us  6  79.605us  42.779us  130.92us  cudaMemcpy
  0.00%  120.71us  4  30.176us  18.506us  35.825us  cuDeviceGetName
  0.00%  109.93us 158     695ns     414ns  1.7770us  cudaSetupArgument
  0.00%  100.97us 104     970ns     571ns  2.1010us  cudaDeviceGetAttribute
  0.00%  83.217us 34  2.4470us     941ns  7.5720us  cudaSetDevice
  0.00%  42.570us  2  21.285us  20.207us  22.363us
cudaStreamCreateWithPriority
  0.00%  37.688us 28  1.3460us     628ns  4.0480us  cudaConfigureCall
  0.00%  35.023us  1  35.023us  35.023us  35.023us  cudaMemsetAsync
  0.00%  31.994us 10  3.1990us  1.8510us  7.2940us  cudaGetDevice
  0.00%  16.583us 20     829ns     596ns  1.1390us  cudaPeekAtLastError
  0.00%  9.4350us  8  1.1790us     555ns  3.8670us  cudaGetLastError
  0.00%  6.7170us  6  1.1190us     525ns  2.4450us  cuDeviceGetCount
  0.00%  6.5240us  1  6.5240us  6.5240us  6.5240us  cudaEventQuery
  0.00%  5.8530us  6     975ns     673ns  1.9630us  cuDeviceGet
  0.00%  4.5010us  3  1.5000us  1.3600us  1.6470us  cuInit
  0.00%  3.8660us  2  1.9330us  1.5120us  2.3540us
cudaDeviceGetStreamPriorityRange
  0.00%  2.8840us  3     961ns     956ns     968ns  cuDriverGetVersion
  0.00%  2.5270us  1  2.5270us  2.5270us  2.5270us  cudaEventRecord
  0.00%  1.6070us  1  1.6070us  1.6070us  1.6070us  cudaGetDeviceCount
```

4. Op Times Comparison (CPU vs GPU):

a). 10000 images (default):

	CPU Time	**GPU Time**
First Layer Op Time:	6.60747 *s*	0.355486 *s*
Second Layer Op Time:	19.537141 *s*	0.652564 *s*

b). 100 images:

	CPU Time	**GPU Time**
First Layer Op Time:	0.065591 *s*	0.003272 *s*
Second Layer Op Time:	0.194542 *s*	0.006654 *s*

c). 10 images:

	CPU Time	**GPU Time**
First Layer Op Time:	0.006572 *s*	0.000260 *s*
Second Layer Op Time:	0.019520 *s*	0.000733 *s*

4. Discussion:

In this milestone we have completed a GPU implementation of the forward convolution. Though there is further optimization added into the new code, we could still observe the significant speed-boost brought by CPU computation. For the default data size, the time spent has been shrunk from 6.6 s to within half a second. This much performance enhancement is exactly why GPU computing is so powerful in many occasions.