Advanced Computer Architecture (HPCA)
HW: GPU (CUDA) Histogram and Atomics

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Files

GPU implementation: histogram64_gpu.cu (Without Atomic ADD support)
histogram64_gpu_atomic.cu (With Atomic ADD support)

Usage

Makefile changes to build histogram64_gpu.cu

```
# Add source files here
EXECUTABLE      := Histogram64_gpu
# Cuda source files (compiled with cudacc)
CUFILES_sm_11   := histogram64_gpu.cu
# C/C++ source files (compiled with gcc / c++)
CCFILES         := #histogram_cpu.cpp


################################################################################
# Rules and targets

include ../../common/common.mk
```

Makefile changes to build histogram64_gpu_atomic.cu

```
# Add source files here
EXECUTABLE      := Histogram64_gpu_atomic
# Cuda source files (compiled with cudacc)
CUFILES_sm_11   := histogram64_gpu_atomic.cu
# C/C++ source files (compiled with gcc / c++)
CCFILES         := #histogram_cpu.cpp


################################################################################
# Rules and targets

include ../../common/common.mk
```

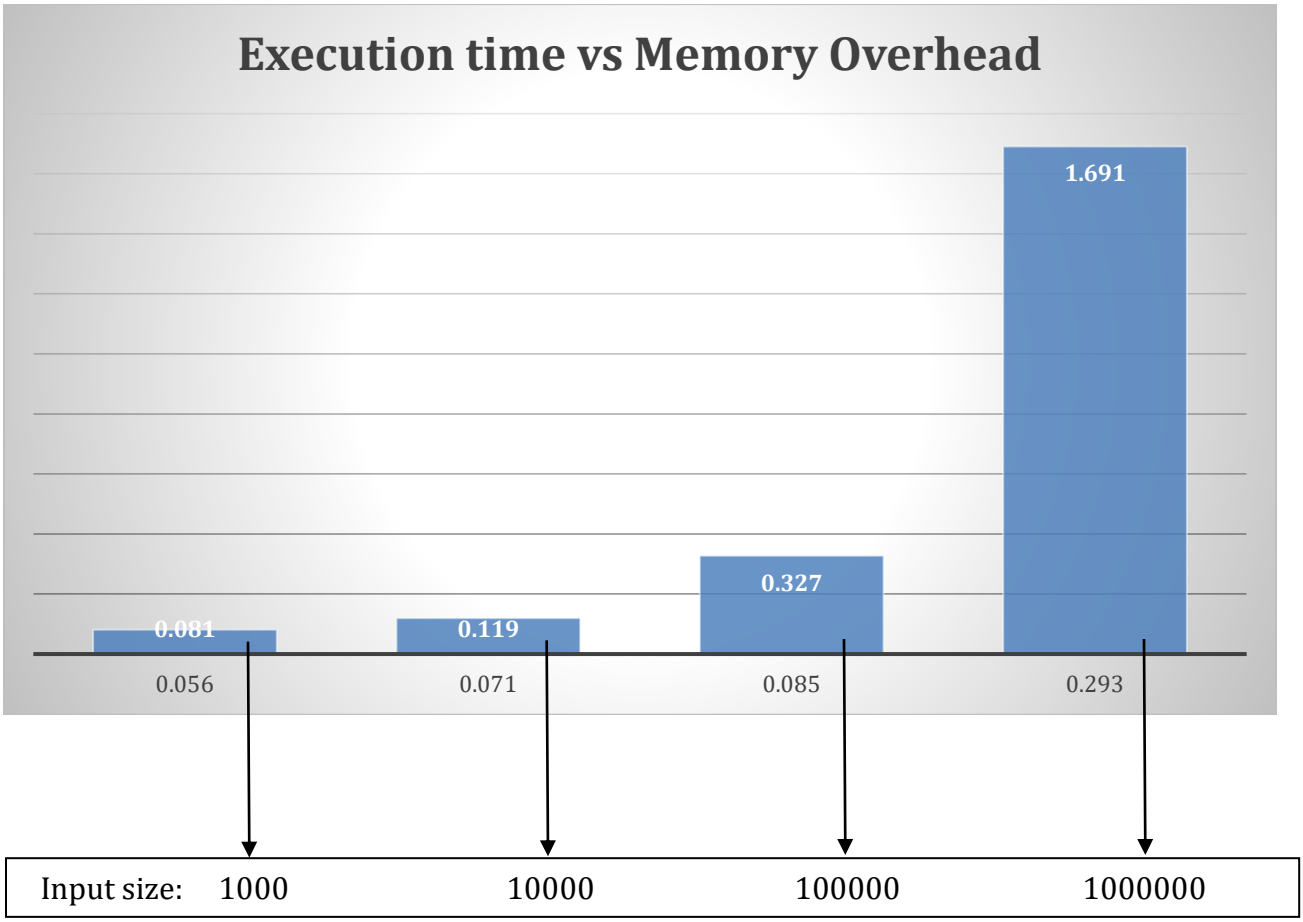
Running histogram64_gpu
./Histogram64_gpu -size 1000

Running histogram64_gpu_atomic
./Histogram64_gpu_atomic -size 1000

Fill in the execution times using the event timers (T=32, H=64)

Array Size (N)	CPU Execution (ms)	GPU Execution + CPU clean up : (ms)	GPU Speedup
1000	0.004	0.056	NA
10000	0.023	0.071	NA
100000	0.212	0.085	59.9 %
1000000	2.324	0.293	87.3 %

You should also include some graphs/analysis of the GPU memory overhead versus GPU computation.



Screenshots

Histogram computation with array size 1000

```
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$ ./Histogra
m64_gpu -size 1000
Histogram : 64 BIN
Input Array size: 1000
Grid Size: 31
CPU to GPU Transfer Time: 0.034000 (ms)
GPU to CPU Transfer Time: 0.047000 (ms)
GPU Execution Time: 0.050 (ms)
CPU Partial Sums Execution time : 0.006 (ms)
CPU Execution time : 0.004 (ms)
CPU and GPU histogram result SAME
CPU_HISTOGRAM   GPU_HISTOGRAM
H_CPU[0] : 11    H_GPU[0] : 11
H_CPU[1] : 16    H_GPU[1] : 16
H_CPU[2] : 18    H_GPU[2] : 18
H_CPU[3] : 11    H_GPU[3] : 11
H_CPU[4] : 13    H_GPU[4] : 13
H_CPU[5] : 14    H_GPU[5] : 14
H_CPU[6] : 12    H_GPU[6] : 12
H_CPU[7] : 19    H_GPU[7] : 19
H_CPU[8] : 13    H_GPU[8] : 13
H_CPU[9] : 19    H_GPU[9] : 19
H_CPU[10] : 18   H_GPU[10] : 18
H_CPU[11] : 16   H_GPU[11] : 16
H_CPU[12] : 12   H_GPU[12] : 12
H_CPU[13] : 25   H_GPU[13] : 25
H_CPU[14] : 16   H_GPU[14] : 16
H_CPU[15] : 14   H_GPU[15] : 14
H_CPU[16] : 13   H_GPU[16] : 13
H_CPU[17] : 15   H_GPU[17] : 15
H_CPU[18] : 10   H_GPU[18] : 10
H_CPU[19] : 13   H_GPU[19] : 13
H_CPU[20] : 22   H_GPU[20] : 22
H_CPU[21] : 17   H_GPU[21] : 17
H_CPU[22] : 17   H_GPU[22] : 17
H_CPU[23] : 13   H_GPU[23] : 13
H_CPU[24] : 20   H_GPU[24] : 20
H_CPU[25] : 15   H_GPU[25] : 15
H_CPU[26] : 21   H_GPU[26] : 21
```

```
H_CPU[27] : 22   H_GPU[27] : 22
H_CPU[28] : 18   H_GPU[28] : 18
H_CPU[29] : 7    H_GPU[29] : 7
H_CPU[30] : 18   H_GPU[30] : 18
H_CPU[31] : 10   H_GPU[31] : 10
H_CPU[32] : 11   H_GPU[32] : 11
H_CPU[33] : 19   H_GPU[33] : 19
H_CPU[34] : 17   H_GPU[34] : 17
H_CPU[35] : 22   H_GPU[35] : 22
H_CPU[36] : 18   H_GPU[36] : 18
H_CPU[37] : 16   H_GPU[37] : 16
H_CPU[38] : 11   H_GPU[38] : 11
H_CPU[39] : 12   H_GPU[39] : 12
H_CPU[40] : 17   H_GPU[40] : 17
H_CPU[41] : 19   H_GPU[41] : 19
H_CPU[42] : 17   H_GPU[42] : 17
H_CPU[43] : 16   H_GPU[43] : 16
H_CPU[44] : 21   H_GPU[44] : 21
H_CPU[45] : 15   H_GPU[45] : 15
H_CPU[46] : 11   H_GPU[46] : 11
H_CPU[47] : 14   H_GPU[47] : 14
H_CPU[48] : 15   H_GPU[48] : 15
H_CPU[49] : 15   H_GPU[49] : 15
H_CPU[50] : 23   H_GPU[50] : 23
H_CPU[51] : 17   H_GPU[51] : 17
H_CPU[52] : 12   H_GPU[52] : 12
H_CPU[53] : 16   H_GPU[53] : 16
H_CPU[54] : 14   H_GPU[54] : 14
H_CPU[55] : 10   H_GPU[55] : 10
H_CPU[56] : 11   H_GPU[56] : 11
H_CPU[57] : 11   H_GPU[57] : 11
H_CPU[58] : 17   H_GPU[58] : 17
H_CPU[59] : 21   H_GPU[59] : 21
H_CPU[60] : 22   H_GPU[60] : 22
H_CPU[61] : 13   H_GPU[61] : 13
H_CPU[62] : 18   H_GPU[62] : 18
H_CPU[63] : 11   H_GPU[63] : 11
```

Histogram computation with array size 10000

```
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$ ./Histogra
m64_gpu -size 10000
Histogram : 64 BIN
Input Array size: 10000
Grid Size: 90
CPU to GPU Transfer Time: 0.063000 (ms)
GPU to CPU Transfer Time: 0.056000 (ms)
GPU Execution Time: 0.052 (ms)
CPU Partial Sums Execution time : 0.019 (ms)
CPU Execution time : 0.023 (ms)
CPU and GPU histogram result SAME
CPU_HISTOGRAM   GPU_HISTOGRAM
H_CPU[0] : 164   H_GPU[0] : 164
H_CPU[1] : 149   H_GPU[1] : 149
H_CPU[2] : 166   H_GPU[2] : 166
H_CPU[3] : 143   H_GPU[3] : 143
H_CPU[4] : 172   H_GPU[4] : 172
H_CPU[5] : 161   H_GPU[5] : 161
H_CPU[6] : 136   H_GPU[6] : 136
H_CPU[7] : 147   H_GPU[7] : 147
H_CPU[8] : 161   H_GPU[8] : 161
H_CPU[9] : 135   H_GPU[9] : 135
H_CPU[10] : 165          H_GPU[10] : 165
H_CPU[11] : 143          H_GPU[11] : 143
H_CPU[12] : 164          H_GPU[12] : 164
H_CPU[13] : 167          H_GPU[13] : 167
H_CPU[14] : 148          H_GPU[14] : 148
H_CPU[15] : 154          H_GPU[15] : 154
H_CPU[16] : 159          H_GPU[16] : 159
H_CPU[17] : 158          H_GPU[17] : 158
H_CPU[18] : 158          H_GPU[18] : 158
H_CPU[19] : 134          H_GPU[19] : 134
H_CPU[20] : 180          H_GPU[20] : 180
H_CPU[21] : 160          H_GPU[21] : 160
H_CPU[22] : 160          H_GPU[22] : 160
H_CPU[23] : 148          H_GPU[23] : 148
H_CPU[24] : 171          H_GPU[24] : 171
H_CPU[25] : 130          H_GPU[25] : 130
H_CPU[26] : 160          H_GPU[26] : 160
H_CPU[27] : 168          H_GPU[27] : 168
H_CPU[28] : 156          H_GPU[28] : 156
H_CPU[29] : 166          H_GPU[29] : 166
H_CPU[30] : 178          H_GPU[30] : 178
H_CPU[31] : 151          H_GPU[31] : 151
H_CPU[32] : 150          H_GPU[32] : 150
H_CPU[33] : 161          H_GPU[33] : 161
H_CPU[34] : 166          H_GPU[34] : 166
H_CPU[35] : 173          H_GPU[35] : 173
H_CPU[36] : 165          H_GPU[36] : 165
H_CPU[37] : 153          H_GPU[37] : 153
H_CPU[38] : 160          H_GPU[38] : 160
H_CPU[39] : 157          H_GPU[39] : 157
H_CPU[40] : 157          H_GPU[40] : 157
H_CPU[41] : 154          H_GPU[41] : 154
H_CPU[42] : 159          H_GPU[42] : 159
H_CPU[43] : 163          H_GPU[43] : 163
H_CPU[44] : 145          H_GPU[44] : 145
H_CPU[45] : 158          H_GPU[45] : 158
H_CPU[46] : 159          H_GPU[46] : 159
H_CPU[47] : 156          H_GPU[47] : 156
H_CPU[48] : 162          H_GPU[48] : 162
H_CPU[49] : 160          H_GPU[49] : 160
H_CPU[50] : 162          H_GPU[50] : 162
H_CPU[51] : 147          H_GPU[51] : 147
H_CPU[52] : 161          H_GPU[52] : 161
H_CPU[53] : 145          H_GPU[53] : 145
H_CPU[54] : 139          H_GPU[54] : 139
H_CPU[55] : 160          H_GPU[55] : 160
H_CPU[56] : 141          H_GPU[56] : 141
H_CPU[57] : 140          H_GPU[57] : 140
H_CPU[58] : 140          H_GPU[58] : 140
H_CPU[59] : 174          H_GPU[59] : 174
H_CPU[60] : 153          H_GPU[60] : 153
H_CPU[61] : 151          H_GPU[61] : 151
H_CPU[62] : 170          H_GPU[62] : 170
H_CPU[63] : 147          H_GPU[63] : 147
```

Histogram computation with array size 100000

```
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$ ./Histogra
m64_gpu -size 100000
Histogram : 64 BIN
Input Array size: 100000
Grid Size: 90
CPU to GPU Transfer Time: 0.272000 (ms)
GPU to CPU Transfer Time: 0.055000 (ms)
GPU Execution Time: 0.066 (ms)
CPU Partial Sums Execution time : 0.019 (ms)
CPU Execution time : 0.212 (ms)
CPU and GPU histogram result SAME
CPU_HISTOGRAM   GPU_HISTOGRAM
H_CPU[0] : 1605          H_GPU[0] : 1605
H_CPU[1] : 1545          H_GPU[1] : 1545
H_CPU[2] : 1539          H_GPU[2] : 1539
H_CPU[3] : 1537          H_GPU[3] : 1537
H_CPU[4] : 1556          H_GPU[4] : 1556
H_CPU[5] : 1590          H_GPU[5] : 1590
H_CPU[6] : 1577          H_GPU[6] : 1577
H_CPU[7] : 1484          H_GPU[7] : 1484
H_CPU[8] : 1467          H_GPU[8] : 1467
H_CPU[9] : 1556          H_GPU[9] : 1556
H_CPU[10] : 1609         H_GPU[10] : 1609
H_CPU[11] : 1555         H_GPU[11] : 1555
H_CPU[12] : 1508         H_GPU[12] : 1508
H_CPU[13] : 1517         H_GPU[13] : 1517
H_CPU[14] : 1565         H_GPU[14] : 1565
H_CPU[15] : 1556         H_GPU[15] : 1556
H_CPU[16] : 1498         H_GPU[16] : 1498
H_CPU[17] : 1526         H_GPU[17] : 1526
H_CPU[18] : 1545         H_GPU[18] : 1545
H_CPU[19] : 1544         H_GPU[19] : 1544
H_CPU[20] : 1679         H_GPU[20] : 1679
H_CPU[21] : 1550         H_GPU[21] : 1550
H_CPU[22] : 1559         H_GPU[22] : 1559
H_CPU[23] : 1586         H_GPU[23] : 1586
H_CPU[24] : 1636         H_GPU[24] : 1636
H_CPU[25] : 1474         H_GPU[25] : 1474
H_CPU[26] : 1564         H_GPU[26] : 1564
H_CPU[27] : 1613         H_GPU[27] : 1613
H_CPU[28] : 1541         H_GPU[28] : 1541
H_CPU[29] : 1494         H_GPU[29] : 1494
H_CPU[30] : 1657         H_GPU[30] : 1657
```

```
H_CPU[30] : 1657         H_GPU[30] : 1657
H_CPU[31] : 1533         H_GPU[31] : 1533
H_CPU[32] : 1537         H_GPU[32] : 1537
H_CPU[33] : 1593         H_GPU[33] : 1593
H_CPU[34] : 1546         H_GPU[34] : 1546
H_CPU[35] : 1601         H_GPU[35] : 1601
H_CPU[36] : 1543         H_GPU[36] : 1543
H_CPU[37] : 1605         H_GPU[37] : 1605
H_CPU[38] : 1586         H_GPU[38] : 1586
H_CPU[39] : 1566         H_GPU[39] : 1566
H_CPU[40] : 1538         H_GPU[40] : 1538
H_CPU[41] : 1589         H_GPU[41] : 1589
H_CPU[42] : 1537         H_GPU[42] : 1537
H_CPU[43] : 1512         H_GPU[43] : 1512
H_CPU[44] : 1612         H_GPU[44] : 1612
H_CPU[45] : 1623         H_GPU[45] : 1623
H_CPU[46] : 1568         H_GPU[46] : 1568
H_CPU[47] : 1578         H_GPU[47] : 1578
H_CPU[48] : 1568         H_GPU[48] : 1568
H_CPU[49] : 1501         H_GPU[49] : 1501
H_CPU[50] : 1586         H_GPU[50] : 1586
H_CPU[51] : 1509         H_GPU[51] : 1509
H_CPU[52] : 1577         H_GPU[52] : 1577
H_CPU[53] : 1596         H_GPU[53] : 1596
H_CPU[54] : 1605         H_GPU[54] : 1605
H_CPU[55] : 1585         H_GPU[55] : 1585
H_CPU[56] : 1571         H_GPU[56] : 1571
H_CPU[57] : 1526         H_GPU[57] : 1526
H_CPU[58] : 1505         H_GPU[58] : 1505
H_CPU[59] : 1620         H_GPU[59] : 1620
H_CPU[60] : 1601         H_GPU[60] : 1601
H_CPU[61] : 1535         H_GPU[61] : 1535
H_CPU[62] : 1659         H_GPU[62] : 1659
H_CPU[63] : 1557         H_GPU[63] : 1557
```

Histogram computation with array size 1000000

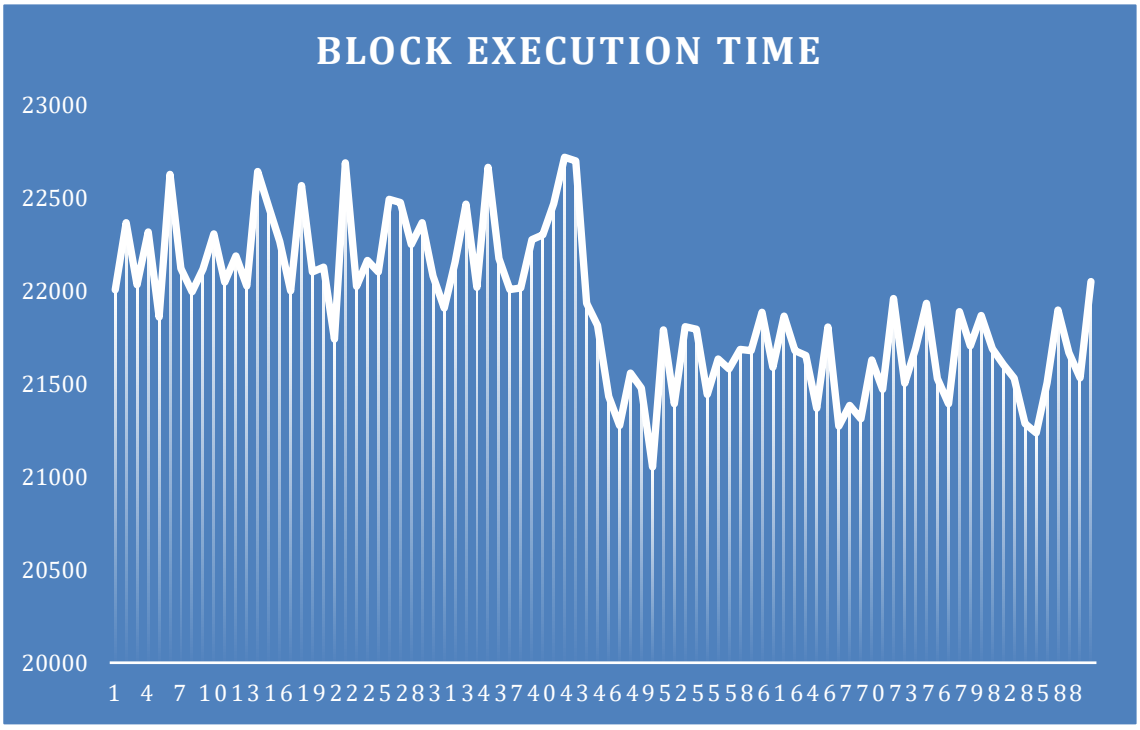
```
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$ ./Histogra
m64_gpu -size 1000000
Histogram : 64 BIN
Input Array size: 1000000
Grid Size: 90
CPU to GPU Transfer Time: 1.635000 (ms)
GPU to CPU Transfer Time: 0.056000 (ms)
GPU Execution Time: 0.274 (ms)
CPU Partial Sums Execution time : 0.019 (ms)
CPU Execution time : 2.324 (ms)
CPU and GPU histogram result SAME
CPU_HISTOGRAM   GPU_HISTOGRAM
H_CPU[0] : 15705         H_GPU[0] : 15705
H_CPU[1] : 15711         H_GPU[1] : 15711
H_CPU[2] : 15717         H_GPU[2] : 15717
H_CPU[3] : 15673         H_GPU[3] : 15673
H_CPU[4] : 15433         H_GPU[4] : 15433
H_CPU[5] : 15695         H_GPU[5] : 15695
H_CPU[6] : 15742         H_GPU[6] : 15742
H_CPU[7] : 15455         H_GPU[7] : 15455
H_CPU[8] : 15446         H_GPU[8] : 15446
H_CPU[9] : 15494         H_GPU[9] : 15494
H_CPU[10] : 15402        H_GPU[10] : 15402
H_CPU[11] : 15685        H_GPU[11] : 15685
H_CPU[12] : 15483        H_GPU[12] : 15483
H_CPU[13] : 15593        H_GPU[13] : 15593
H_CPU[14] : 15560        H_GPU[14] : 15560
H_CPU[15] : 15539        H_GPU[15] : 15539
H_CPU[16] : 15690        H_GPU[16] : 15690
H_CPU[17] : 15645        H_GPU[17] : 15645
H_CPU[18] : 15609        H_GPU[18] : 15609
H_CPU[19] : 15671        H_GPU[19] : 15671
H_CPU[20] : 15588        H_GPU[20] : 15588
H_CPU[21] : 15619        H_GPU[21] : 15619
H_CPU[22] : 15563        H_GPU[22] : 15563
H_CPU[23] : 15681        H_GPU[23] : 15681
H_CPU[24] : 15628        H_GPU[24] : 15628
H_CPU[25] : 15461        H_GPU[25] : 15461
H_CPU[26] : 15477        H_GPU[26] : 15477
H_CPU[27] : 15668        H_GPU[27] : 15668
H_CPU[28] : 15616        H_GPU[28] : 15616
H_CPU[29] : 15534        H_GPU[29] : 15534
H_CPU[30] : 15727        H_GPU[30] : 15727
```

```
H_CPU[31] : 15571        H_GPU[31] : 15571
H_CPU[32] : 15473        H_GPU[32] : 15473
H_CPU[33] : 15672        H_GPU[33] : 15672
H_CPU[34] : 15587        H_GPU[34] : 15587
H_CPU[35] : 15768        H_GPU[35] : 15768
H_CPU[36] : 15769        H_GPU[36] : 15769
H_CPU[37] : 15738        H_GPU[37] : 15738
H_CPU[38] : 15584        H_GPU[38] : 15584
H_CPU[39] : 15665        H_GPU[39] : 15665
H_CPU[40] : 15653        H_GPU[40] : 15653
H_CPU[41] : 15598        H_GPU[41] : 15598
H_CPU[42] : 15703        H_GPU[42] : 15703
H_CPU[43] : 15595        H_GPU[43] : 15595
H_CPU[44] : 15720        H_GPU[44] : 15720
H_CPU[45] : 15627        H_GPU[45] : 15627
H_CPU[46] : 15826        H_GPU[46] : 15826
H_CPU[47] : 15741        H_GPU[47] : 15741
H_CPU[48] : 15471        H_GPU[48] : 15471
H_CPU[49] : 15672        H_GPU[49] : 15672
H_CPU[50] : 15699        H_GPU[50] : 15699
H_CPU[51] : 15511        H_GPU[51] : 15511
H_CPU[52] : 15896        H_GPU[52] : 15896
H_CPU[53] : 15588        H_GPU[53] : 15588
H_CPU[54] : 15512        H_GPU[54] : 15512
H_CPU[55] : 15667        H_GPU[55] : 15667
H_CPU[56] : 15690        H_GPU[56] : 15690
H_CPU[57] : 15417        H_GPU[57] : 15417
H_CPU[58] : 15615        H_GPU[58] : 15615
H_CPU[59] : 15627        H_GPU[59] : 15627
H_CPU[60] : 15780        H_GPU[60] : 15780
H_CPU[61] : 15458        H_GPU[61] : 15458
H_CPU[62] : 15791        H_GPU[62] : 15791
H_CPU[63] : 15806        H_GPU[63] : 15806
```

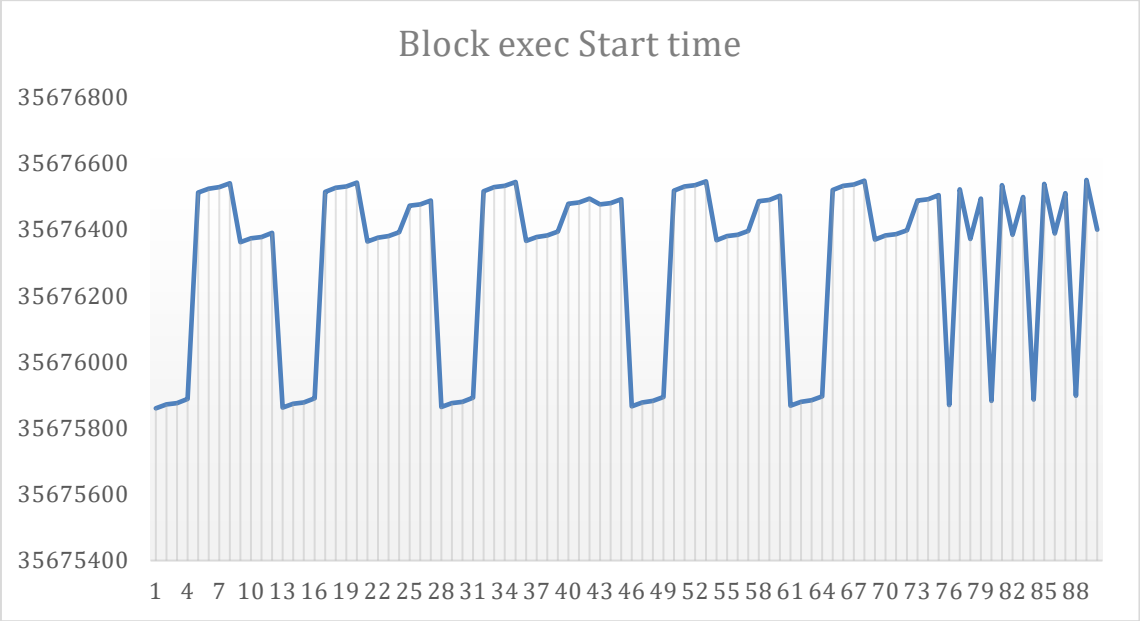
[Item 2] – For the assignment, you need to insert the clock() function within the CUDA kernel to perform performance evaluation of the following:

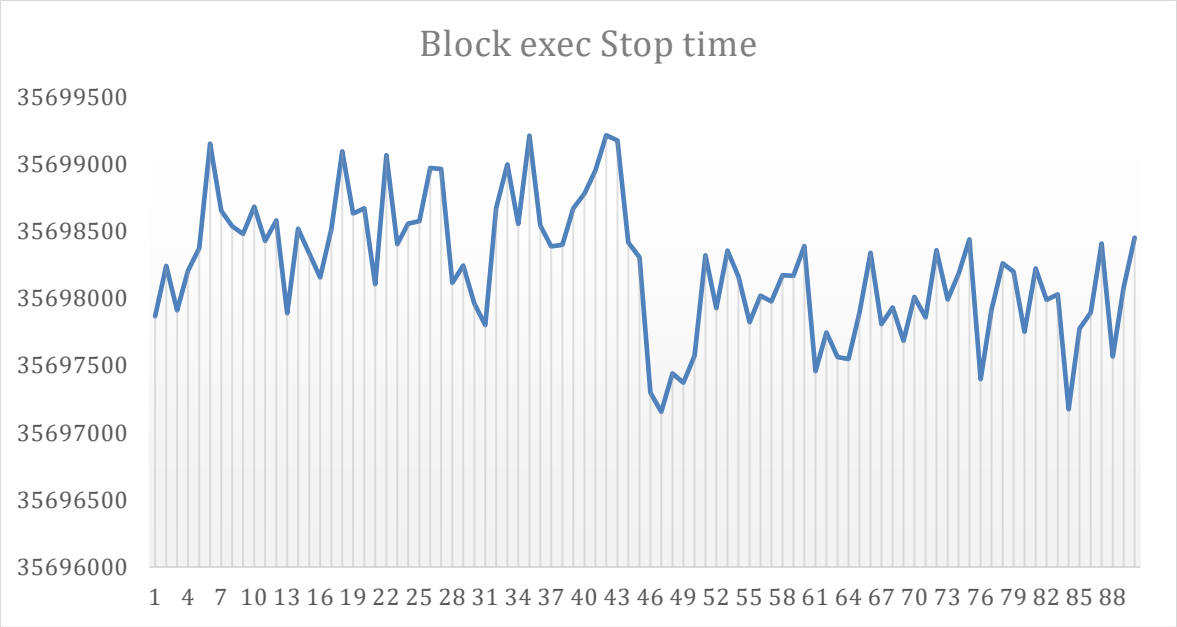
Build a histogram of the block execution times (start of a block to completion of a block). Note- the goal is to classify the execution times of the blocks. Use T=32, H=64, N=10000

(a) Draw a histogram using Matlab or Microsoft Excel showing the block execution times.



(b) Draw a timeline showing when the blocks execute (start to finish)





Answer the following questions:

```
B83     35675886        35697174        21288
B84     35676538        35697776        21238
B85     35676388        35697896        21508
B86     35676510        35698410        21900
B87     35675898        35697568        21670
B88     35676550        35698084        21534
B89     35676400        35698452        22052
-----------------------------------------------------------------
Exec time for shortest running block: 21054
Exec time for longest running block: 22722
Exec time for the last Block - B[88](start time :35676550) :21534
-----------------------------------------------------------------
```

What time execution for the shortest running block?
21054

How much execution time occurs at the end of the execution (when all N-1 blocks have finished, but there is only 1 remaining block waiting to finish)?
21534

Screenshots

Block execution times for Histogram array size 10000

BLOCK EXECUTION TIME

Block	Start_time	End_time	Exec_time
B0	35675860	35697868	22008
B1	35675872	35698242	22370
B2	35675876	35697912	22036
B3	35675888	35698208	22320
B4	35676512	35698374	21862
B5	35676524	35699154	22630
B6	35676528	35698652	22124
B7	35676540	35698538	21998
B8	35676362	35698482	22120
B9	35676374	35698684	22310
B10	35676378	35698428	22050
B11	35676390	35698580	22190
B12	35675862	35697890	22028
B13	35675874	35698520	22646
B14	35675878	35698336	22458
B15	35675890	35698158	22268
B16	35676514	35698516	22002
B17	35676526	35699096	22570
B18	35676530	35698634	22104
B19	35676542	35698672	22130
B20	35676364	35698106	21742
B21	35676376	35699068	22692
B22	35676380	35698406	22026
B23	35676392	35698558	22166
B24	35676472	35698576	22104
B25	35676476	35698972	22496
B26	35676488	35698966	22478
B27	35675864	35698116	22252
B28	35675876	35698246	22370
B29	35675880	35697962	22082
B30	35675892	35697802	21910
B31	35676516	35698674	22158
B32	35676528	35698998	22470
B33	35676532	35698554	22022
B34	35676544	35699212	22668
B35	35676366	35698542	22176
B36	35676378	35698388	22010
B37	35676382	35698400	22018
B38	35676394	35698672	22278
B39	35676478	35698782	22304
B40	35676482	35698954	22472

B41	35676494	35699216	22722
B42	35676476	35699178	22702
B43	35676480	35698416	21936
B44	35676492	35698308	21816
B45	35675866	35697300	21434
B46	35675878	35697156	21278
B47	35675882	35697442	21560
B48	35675894	35697372	21478
B49	35676518	35697572	21054
B50	35676530	35698322	21792
B51	35676534	35697928	21394
B52	35676546	35698356	21810
B53	35676368	35698164	21796
B54	35676380	35697824	21444
B55	35676384	35698020	21636
B56	35676396	35697978	21582
B57	35676486	35698174	21688
B58	35676490	35698170	21680
B59	35676502	35698390	21888
B60	35675868	35697458	21590
B61	35675880	35697746	21866
B62	35675884	35697564	21680
B63	35675896	35697550	21654
B64	35676520	35697890	21370
B65	35676532	35698340	21808
B66	35676536	35697810	21274
B67	35676548	35697934	21386
B68	35676370	35697684	21314
B69	35676382	35698012	21630
B70	35676386	35697858	21472
B71	35676398	35698360	21962
B72	35676488	35697992	21504
B73	35676492	35698184	21692
B74	35676504	35698440	21936
B75	35675870	35697400	21530
B76	35676522	35697916	21394
B77	35676372	35698262	21890
B78	35676494	35698200	21706
B79	35675882	35697752	21870
B80	35676534	35698224	21690
B81	35676384	35697990	21606
B82	35676498	35698030	21532
B83	35675886	35697174	21288

```
B83     35675886        35697174        21288
B84     35676538        35697776        21238
B85     35676388        35697896        21508
B86     35676510        35698410        21900
B87     35675898        35697568        21670
B88     35676550        35698084        21534
B89     35676400        35698452        22052
----------------------------------------------------------------
Exec time for shortest running block: 21054
Exec time for longest running block: 22722
Exec time for the last Block - B[88](start time :35676550) :21534
----------------------------------------------------------------
```

[Item 3] – histogram_atomic_kernel: You are to examine an optimization through the use of an atomic instruction to enforce one thread at a time accessing to individual locations in the histogram array.

Array Size (N)	GPU Execution + CPU clean up : **histogram_kernel** (ms)	GPU Execution + CPU clean up : **histogram_atomic_kernel** (ms)	Speedup %
1000	0.056	0.050	10.7
10000	0.071	0.052	26.7
100000	0.085	0.071	16.4
1000000	0.293	0.280	4.4

Screenshots

Atomic Histogram calculation with array size 1000

```
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$ ./Histogra
m64_gpu_atomic -size 1000
Histogram : 64 BIN
Input Array size: 1000
Grid Size: 31
CPU to GPU Transfer Time: 0.042000 (ms)
GPU to CPU Transfer Time: 0.029000 (ms)
GPU Execution Time: 0.050 (ms)
CPU Execution time : 0.004 (ms)
CPU and GPU histogram result SAME
CPU_HISTOGRAM   GPU_HISTOGRAM
H_CPU[0] : 11    H_GPU[0] : 11
H_CPU[1] : 16    H_GPU[1] : 16
H_CPU[2] : 18    H_GPU[2] : 18
H_CPU[3] : 11    H_GPU[3] : 11
H_CPU[4] : 13    H_GPU[4] : 13
H_CPU[5] : 14    H_GPU[5] : 14
H_CPU[6] : 12    H_GPU[6] : 12
H_CPU[7] : 19    H_GPU[7] : 19
H_CPU[8] : 13    H_GPU[8] : 13
H_CPU[9] : 19    H_GPU[9] : 19
H_CPU[10] : 18   H_GPU[10] : 18
H_CPU[11] : 16   H_GPU[11] : 16
H_CPU[12] : 12   H_GPU[12] : 12
H_CPU[13] : 25   H_GPU[13] : 25
H_CPU[14] : 16   H_GPU[14] : 16
H_CPU[15] : 14   H_GPU[15] : 14
H_CPU[16] : 13   H_GPU[16] : 13
H_CPU[17] : 15   H_GPU[17] : 15
H_CPU[18] : 10   H_GPU[18] : 10
H_CPU[19] : 13   H_GPU[19] : 13
H_CPU[20] : 22   H_GPU[20] : 22
H_CPU[21] : 17   H_GPU[21] : 17
H_CPU[22] : 17   H_GPU[22] : 17
H_CPU[23] : 13   H_GPU[23] : 13
H_CPU[24] : 20   H_GPU[24] : 20
H_CPU[25] : 15   H_GPU[25] : 15
H_CPU[26] : 21   H_GPU[26] : 21
H_CPU[27] : 22   H_GPU[27] : 22
H_CPU[28] : 18   H_GPU[28] : 18
H_CPU[29] : 7    H_GPU[29] : 7
H_CPU[30] : 18   H_GPU[30] : 18
```

```
H_CPU[31] : 10   H_GPU[31] : 10
H_CPU[32] : 11   H_GPU[32] : 11
H_CPU[33] : 19   H_GPU[33] : 19
H_CPU[34] : 17   H_GPU[34] : 17
H_CPU[35] : 22   H_GPU[35] : 22
H_CPU[36] : 18   H_GPU[36] : 18
H_CPU[37] : 16   H_GPU[37] : 16
H_CPU[38] : 11   H_GPU[38] : 11
H_CPU[39] : 12   H_GPU[39] : 12
H_CPU[40] : 17   H_GPU[40] : 17
H_CPU[41] : 19   H_GPU[41] : 19
H_CPU[42] : 17   H_GPU[42] : 17
H_CPU[43] : 16   H_GPU[43] : 16
H_CPU[44] : 21   H_GPU[44] : 21
H_CPU[45] : 15   H_GPU[45] : 15
H_CPU[46] : 11   H_GPU[46] : 11
H_CPU[47] : 14   H_GPU[47] : 14
H_CPU[48] : 15   H_GPU[48] : 15
H_CPU[49] : 15   H_GPU[49] : 15
H_CPU[50] : 23   H_GPU[50] : 23
H_CPU[51] : 17   H_GPU[51] : 17
H_CPU[52] : 12   H_GPU[52] : 12
H_CPU[53] : 16   H_GPU[53] : 16
H_CPU[54] : 14   H_GPU[54] : 14
H_CPU[55] : 10   H_GPU[55] : 10
H_CPU[56] : 11   H_GPU[56] : 11
H_CPU[57] : 11   H_GPU[57] : 11
H_CPU[58] : 17   H_GPU[58] : 17
H_CPU[59] : 21   H_GPU[59] : 21
H_CPU[60] : 22   H_GPU[60] : 22
H_CPU[61] : 13   H_GPU[61] : 13
H_CPU[62] : 18   H_GPU[62] : 18
H_CPU[63] : 11   H_GPU[63] : 11
```

Atomic Histogram calculation with array size 10000

```
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$ ./Histogra
m64_gpu_atomic -size 10000
Histogram : 64 BIN
Input Array size: 10000
Grid Size: 90
CPU to GPU Transfer Time: 0.075000 (ms)
GPU to CPU Transfer Time: 0.030000 (ms)
GPU Execution Time: 0.052 (ms)
CPU Execution time : 0.023 (ms)
CPU and GPU histogram result SAME
CPU_HISTOGRAM   GPU_HISTOGRAM
H_CPU[0] : 164   H_GPU[0] : 164
H_CPU[1] : 149   H_GPU[1] : 149
H_CPU[2] : 166   H_GPU[2] : 166
H_CPU[3] : 143   H_GPU[3] : 143
H_CPU[4] : 172   H_GPU[4] : 172
H_CPU[5] : 161   H_GPU[5] : 161
H_CPU[6] : 136   H_GPU[6] : 136
H_CPU[7] : 147   H_GPU[7] : 147
H_CPU[8] : 161   H_GPU[8] : 161
H_CPU[9] : 135   H_GPU[9] : 135
H_CPU[10] : 165          H_GPU[10] : 165
H_CPU[11] : 143          H_GPU[11] : 143
H_CPU[12] : 164          H_GPU[12] : 164
H_CPU[13] : 167          H_GPU[13] : 167
H_CPU[14] : 148          H_GPU[14] : 148
H_CPU[15] : 154          H_GPU[15] : 154
H_CPU[16] : 159          H_GPU[16] : 159
H_CPU[17] : 158          H_GPU[17] : 158
H_CPU[18] : 158          H_GPU[18] : 158
H_CPU[19] : 134          H_GPU[19] : 134
H_CPU[20] : 180          H_GPU[20] : 180
H_CPU[21] : 160          H_GPU[21] : 160
H_CPU[22] : 160          H_GPU[22] : 160
H_CPU[23] : 148          H_GPU[23] : 148
H_CPU[24] : 171          H_GPU[24] : 171
H_CPU[25] : 130          H_GPU[25] : 130
H_CPU[26] : 160          H_GPU[26] : 160
H_CPU[27] : 168          H_GPU[27] : 168
H_CPU[28] : 156          H_GPU[28] : 156
H_CPU[29] : 166          H_GPU[29] : 166
H_CPU[30] : 178          H_GPU[30] : 178
H_CPU[31] : 151          H_GPU[31] : 151
H_CPU[32] : 150          H_GPU[32] : 150
```

```
H_CPU[32] : 150          H_GPU[32] : 150
H_CPU[33] : 161          H_GPU[33] : 161
H_CPU[34] : 166          H_GPU[34] : 166
H_CPU[35] : 173          H_GPU[35] : 173
H_CPU[36] : 165          H_GPU[36] : 165
H_CPU[37] : 153          H_GPU[37] : 153
H_CPU[38] : 160          H_GPU[38] : 160
H_CPU[39] : 157          H_GPU[39] : 157
H_CPU[40] : 157          H_GPU[40] : 157
H_CPU[41] : 154          H_GPU[41] : 154
H_CPU[42] : 159          H_GPU[42] : 159
H_CPU[43] : 163          H_GPU[43] : 163
H_CPU[44] : 145          H_GPU[44] : 145
H_CPU[45] : 158          H_GPU[45] : 158
H_CPU[46] : 159          H_GPU[46] : 159
H_CPU[47] : 156          H_GPU[47] : 156
H_CPU[48] : 162          H_GPU[48] : 162
H_CPU[49] : 160          H_GPU[49] : 160
H_CPU[50] : 162          H_GPU[50] : 162
H_CPU[51] : 147          H_GPU[51] : 147
H_CPU[52] : 161          H_GPU[52] : 161
H_CPU[53] : 145          H_GPU[53] : 145
H_CPU[54] : 139          H_GPU[54] : 139
H_CPU[55] : 160          H_GPU[55] : 160
H_CPU[56] : 141          H_GPU[56] : 141
H_CPU[57] : 140          H_GPU[57] : 140
H_CPU[58] : 140          H_GPU[58] : 140
H_CPU[59] : 174          H_GPU[59] : 174
H_CPU[60] : 153          H_GPU[60] : 153
H_CPU[61] : 151          H_GPU[61] : 151
H_CPU[62] : 170          H_GPU[62] : 170
H_CPU[63] : 147          H_GPU[63] : 147
```

Atomic Histogram calculation with array size 100000

```
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$ ./Histogra
m64_gpu_atomic -size 100000
Histogram : 64 BIN
Input Array size: 100000
Grid Size: 90
CPU to GPU Transfer Time: 0.291000 (ms)
GPU to CPU Transfer Time: 0.031000 (ms)
GPU Execution Time: 0.071 (ms)
CPU Execution time : 0.214 (ms)
CPU and GPU histogram result SAME
CPU_HISTOGRAM   GPU_HISTOGRAM
H_CPU[0] : 1605          H_GPU[0] : 1605
H_CPU[1] : 1545          H_GPU[1] : 1545
H_CPU[2] : 1539          H_GPU[2] : 1539
H_CPU[3] : 1537          H_GPU[3] : 1537
H_CPU[4] : 1556          H_GPU[4] : 1556
H_CPU[5] : 1590          H_GPU[5] : 1590
H_CPU[6] : 1577          H_GPU[6] : 1577
H_CPU[7] : 1484          H_GPU[7] : 1484
H_CPU[8] : 1467          H_GPU[8] : 1467
H_CPU[9] : 1556          H_GPU[9] : 1556
H_CPU[10] : 1609         H_GPU[10] : 1609
H_CPU[11] : 1555         H_GPU[11] : 1555
H_CPU[12] : 1508         H_GPU[12] : 1508
H_CPU[13] : 1517         H_GPU[13] : 1517
H_CPU[14] : 1565         H_GPU[14] : 1565
H_CPU[15] : 1556         H_GPU[15] : 1556
H_CPU[16] : 1498         H_GPU[16] : 1498
H_CPU[17] : 1526         H_GPU[17] : 1526
H_CPU[18] : 1545         H_GPU[18] : 1545
H_CPU[19] : 1544         H_GPU[19] : 1544
H_CPU[20] : 1679         H_GPU[20] : 1679
H_CPU[21] : 1550         H_GPU[21] : 1550
H_CPU[22] : 1559         H_GPU[22] : 1559
H_CPU[23] : 1586         H_GPU[23] : 1586
H_CPU[24] : 1636         H_GPU[24] : 1636
H_CPU[25] : 1474         H_GPU[25] : 1474
H_CPU[26] : 1564         H_GPU[26] : 1564
H_CPU[27] : 1613         H_GPU[27] : 1613
H_CPU[28] : 1541         H_GPU[28] : 1541
H_CPU[29] : 1494         H_GPU[29] : 1494
H_CPU[30] : 1657         H_GPU[30] : 1657
H_CPU[31] : 1533         H_GPU[31] : 1533
H_CPU[32] : 1537         H_GPU[32] : 1537
```

```
H_CPU[32] : 1537         H_GPU[32] : 1537
H_CPU[33] : 1593         H_GPU[33] : 1593
H_CPU[34] : 1546         H_GPU[34] : 1546
H_CPU[35] : 1601         H_GPU[35] : 1601
H_CPU[36] : 1543         H_GPU[36] : 1543
H_CPU[37] : 1605         H_GPU[37] : 1605
H_CPU[38] : 1586         H_GPU[38] : 1586
H_CPU[39] : 1566         H_GPU[39] : 1566
H_CPU[40] : 1538         H_GPU[40] : 1538
H_CPU[41] : 1589         H_GPU[41] : 1589
H_CPU[42] : 1537         H_GPU[42] : 1537
H_CPU[43] : 1512         H_GPU[43] : 1512
H_CPU[44] : 1612         H_GPU[44] : 1612
H_CPU[45] : 1623         H_GPU[45] : 1623
H_CPU[46] : 1568         H_GPU[46] : 1568
H_CPU[47] : 1578         H_GPU[47] : 1578
H_CPU[48] : 1568         H_GPU[48] : 1568
H_CPU[49] : 1501         H_GPU[49] : 1501
H_CPU[50] : 1586         H_GPU[50] : 1586
H_CPU[51] : 1509         H_GPU[51] : 1509
H_CPU[52] : 1577         H_GPU[52] : 1577
H_CPU[53] : 1596         H_GPU[53] : 1596
H_CPU[54] : 1605         H_GPU[54] : 1605
H_CPU[55] : 1585         H_GPU[55] : 1585
H_CPU[56] : 1571         H_GPU[56] : 1571
H_CPU[57] : 1526         H_GPU[57] : 1526
H_CPU[58] : 1505         H_GPU[58] : 1505
H_CPU[59] : 1620         H_GPU[59] : 1620
H_CPU[60] : 1601         H_GPU[60] : 1601
H_CPU[61] : 1535         H_GPU[61] : 1535
H_CPU[62] : 1659         H_GPU[62] : 1659
H_CPU[63] : 1557         H_GPU[63] : 1557
```

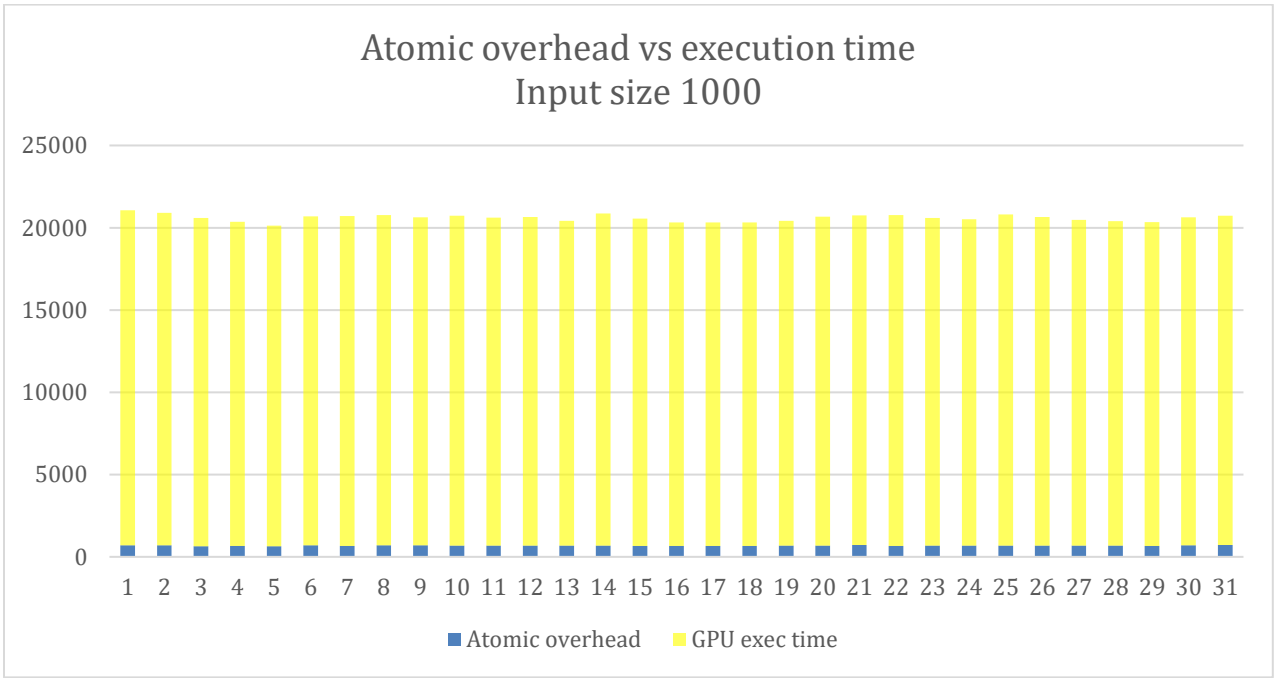
Atomic Histogram calculation with array size 1000000

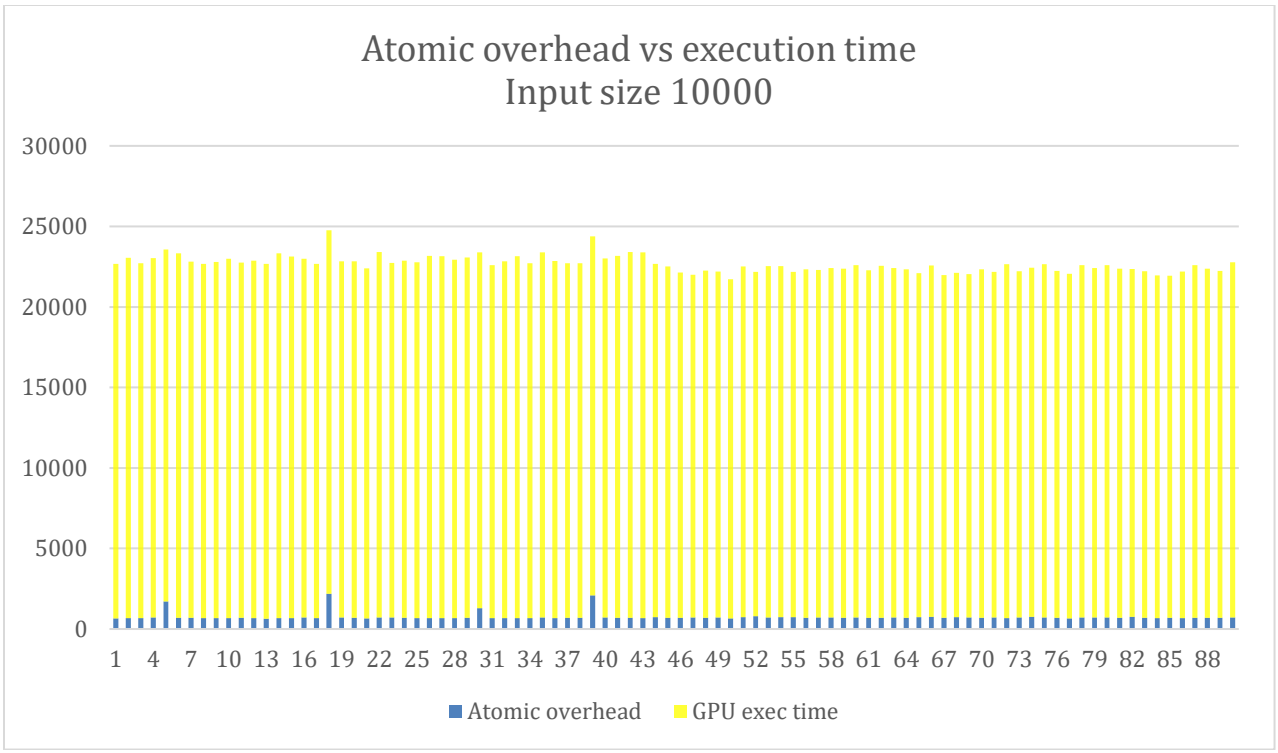
```
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$ ./Histogra
m64_gpu_atomic -size 1000000
Histogram : 64 BIN
Input Array size: 1000000
Grid Size: 90
CPU to GPU Transfer Time: 1.637000 (ms)
GPU to CPU Transfer Time: 0.030000 (ms)
GPU Execution Time: 0.280 (ms)
CPU Execution time : 2.308 (ms)
CPU and GPU histogram result SAME
CPU_HISTOGRAM   GPU_HISTOGRAM
H_CPU[0] : 15705         H_GPU[0] : 15705
H_CPU[1] : 15711         H_GPU[1] : 15711
H_CPU[2] : 15717         H_GPU[2] : 15717
H_CPU[3] : 15673         H_GPU[3] : 15673
H_CPU[4] : 15433         H_GPU[4] : 15433
H_CPU[5] : 15695         H_GPU[5] : 15695
H_CPU[6] : 15742         H_GPU[6] : 15742
H_CPU[7] : 15455         H_GPU[7] : 15455
H_CPU[8] : 15446         H_GPU[8] : 15446
H_CPU[9] : 15494         H_GPU[9] : 15494
H_CPU[10] : 15402        H_GPU[10] : 15402
H_CPU[11] : 15685        H_GPU[11] : 15685
H_CPU[12] : 15483        H_GPU[12] : 15483
H_CPU[13] : 15593        H_GPU[13] : 15593
H_CPU[14] : 15560        H_GPU[14] : 15560
H_CPU[15] : 15539        H_GPU[15] : 15539
H_CPU[16] : 15690        H_GPU[16] : 15690
H_CPU[17] : 15645        H_GPU[17] : 15645
H_CPU[18] : 15609        H_GPU[18] : 15609
H_CPU[19] : 15671        H_GPU[19] : 15671
H_CPU[20] : 15588        H_GPU[20] : 15588
H_CPU[21] : 15619        H_GPU[21] : 15619
H_CPU[22] : 15563        H_GPU[22] : 15563
H_CPU[23] : 15681        H_GPU[23] : 15681
H_CPU[24] : 15628        H_GPU[24] : 15628
H_CPU[25] : 15461        H_GPU[25] : 15461
H_CPU[26] : 15477        H_GPU[26] : 15477
H_CPU[27] : 15668        H_GPU[27] : 15668
H_CPU[28] : 15616        H_GPU[28] : 15616
H_CPU[29] : 15534        H_GPU[29] : 15534
H_CPU[30] : 15727        H_GPU[30] : 15727
H_CPU[31] : 15571        H_GPU[31] : 15571
H_CPU[32] : 15473        H_GPU[32] : 15473
```

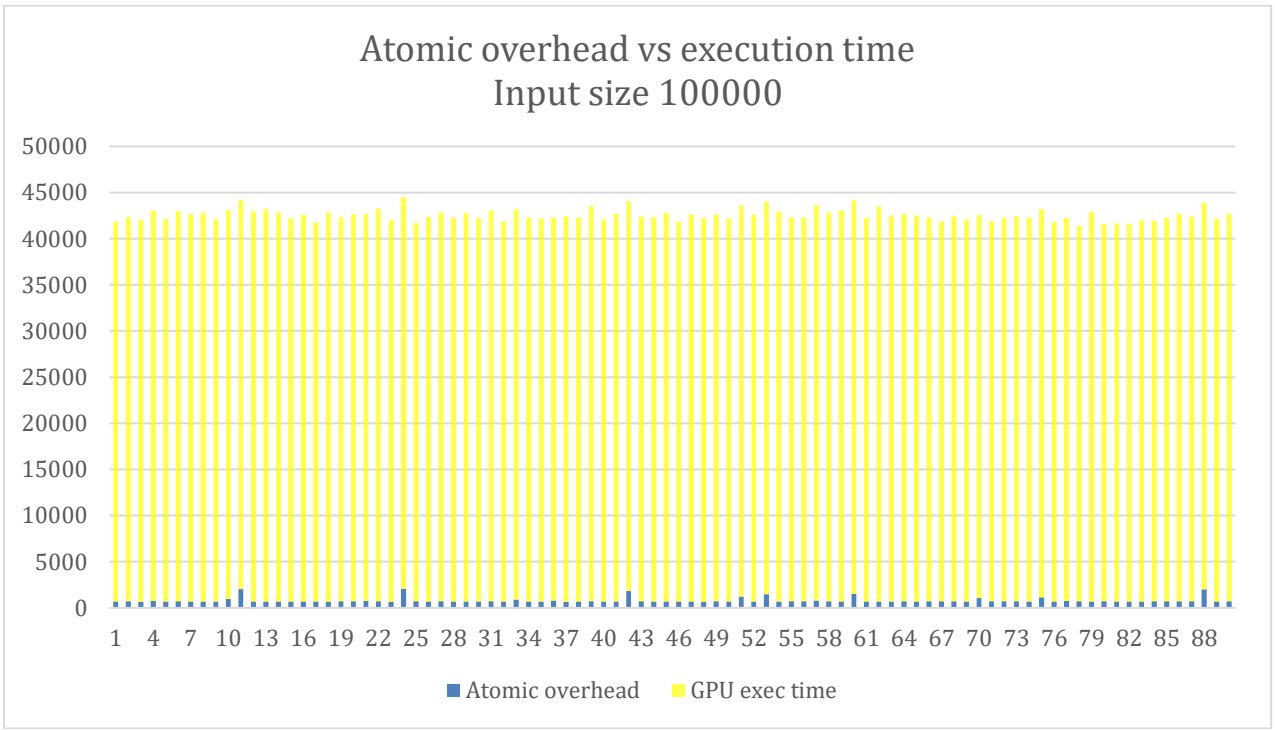
```
H_CPU[31] : 15571        H_GPU[31] : 15571
H_CPU[32] : 15473        H_GPU[32] : 15473
H_CPU[33] : 15672        H_GPU[33] : 15672
H_CPU[34] : 15587        H_GPU[34] : 15587
H_CPU[35] : 15768        H_GPU[35] : 15768
H_CPU[36] : 15769        H_GPU[36] : 15769
H_CPU[37] : 15738        H_GPU[37] : 15738
H_CPU[38] : 15584        H_GPU[38] : 15584
H_CPU[39] : 15665        H_GPU[39] : 15665
H_CPU[40] : 15653        H_GPU[40] : 15653
H_CPU[41] : 15598        H_GPU[41] : 15598
H_CPU[42] : 15703        H_GPU[42] : 15703
H_CPU[43] : 15595        H_GPU[43] : 15595
H_CPU[44] : 15720        H_GPU[44] : 15720
H_CPU[45] : 15627        H_GPU[45] : 15627
H_CPU[46] : 15826        H_GPU[46] : 15826
H_CPU[47] : 15741        H_GPU[47] : 15741
H_CPU[48] : 15471        H_GPU[48] : 15471
H_CPU[49] : 15672        H_GPU[49] : 15672
H_CPU[50] : 15699        H_GPU[50] : 15699
H_CPU[51] : 15511        H_GPU[51] : 15511
H_CPU[52] : 15896        H_GPU[52] : 15896
H_CPU[53] : 15588        H_GPU[53] : 15588
H_CPU[54] : 15512        H_GPU[54] : 15512
H_CPU[55] : 15667        H_GPU[55] : 15667
H_CPU[56] : 15690        H_GPU[56] : 15690
H_CPU[57] : 15417        H_GPU[57] : 15417
H_CPU[58] : 15615        H_GPU[58] : 15615
H_CPU[59] : 15627        H_GPU[59] : 15627
H_CPU[60] : 15780        H_GPU[60] : 15780
H_CPU[61] : 15458        H_GPU[61] : 15458
H_CPU[62] : 15791        H_GPU[62] : 15791
H_CPU[63] : 15806        H_GPU[63] : 15806
```

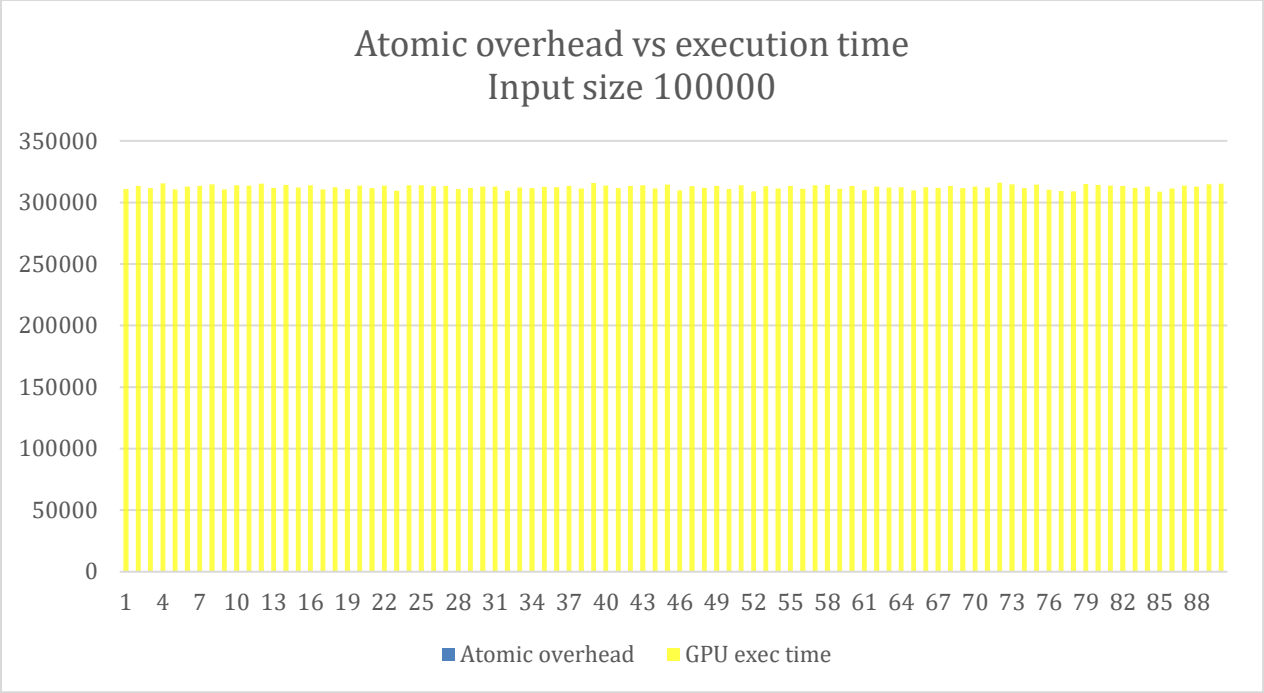
[Item 4] – You are to use the clock() to time the activity of "atomicAdd" You will need to build an output result array that each block of threads will write to the output time.

You will describe (Microsoft excel graphs, etc) the overhead of atomics within the GPU system.




Atomic overhead vs execution time
Input size 10000
30000
25000
20000
15000
10000
5000
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88
Atomic overhead
GPU exec time


Atomic overhead vs execution time
Input size 100000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88
Atomic overhead
GPU exec time



Screenshots

Atomic Add Overhead in Histogram calculation with array size 1000

```
----------------------------------------
Atomic Add times of each block
----------------------------------------
BLOCK   TIME
B[0]    698
B[1]    692
B[2]    650
B[3]    668
B[4]    646
B[5]    694
B[6]    670
B[7]    692
B[8]    696
B[9]    688
B[10]   680
B[11]   686
B[12]   676
B[13]   684
B[14]   666
B[15]   666
B[16]   660
B[17]   664
B[18]   686
B[19]   680
B[20]   716
B[21]   666
B[22]   678
B[23]   690
B[24]   682
B[25]   690
B[26]   688
B[27]   680
B[28]   656
B[29]   696
B[30]   716
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$
```

Atomic Add Overhead in Histogram calculation with array size 10000

```
----------------------------------------
Atomic Add times of each block
----------------------------------------
BLOCK   TIME
B[0]    666
B[1]    674
B[2]    674
B[3]    716
B[4]    1710
B[5]    696
B[6]    696
B[7]    668
B[8]    676
B[9]    686
B[10]   694
B[11]   674
B[12]   646
B[13]   678
B[14]   668
B[15]   718
B[16]   676
B[17]   2192
B[18]   726
B[19]   698
B[20]   660
B[21]   714
B[22]   710
B[23]   696
B[24]   674
B[25]   676
B[26]   680
B[27]   686
B[28]   704
B[29]   1300
B[30]   676
B[31]   680
B[32]   686
B[33]   682
B[34]   724
B[35]   682
B[36]   698
B[37]   698
B[38]   2096
B[39]   716
```

```
B[39]   716
B[40]   698
B[41]   690
B[42]   682
B[43]   744
B[44]   704
B[45]   698
B[46]   720
B[47]   694
B[48]   726
B[49]   662
B[50]   728
B[51]   790
B[52]   718
B[53]   734
B[54]   742
B[55]   694
B[56]   716
B[57]   724
B[58]   696
B[59]   714
B[60]   692
B[61]   694
B[62]   726
B[63]   690
B[64]   732
B[65]   760
B[66]   706
B[67]   738
B[68]   718
B[69]   704
B[70]   710
B[71]   686
B[72]   714
B[73]   748
B[74]   710
B[75]   700
B[76]   664
B[77]   708
B[78]   710
B[79]   722
B[80]   694
B[81]   758
B[82]   690
```

```
B[80]   694
B[81]   758
B[82]   690
B[83]   676
B[84]   700
B[85]   682
B[86]   700
B[87]   700
B[88]   694
B[89]   712
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$
```

Atomic Add Overhead in Histogram calculation with array size 100000

```
----------------------------------------
Atomic Add times of each block
----------------------------------------
BLOCK   TIME
B[0]    670
B[1]    726
B[2]    646
B[3]    762
B[4]    678
B[5]    698
B[6]    666
B[7]    674
B[8]    678
B[9]    946
B[10]   2024
B[11]   688
B[12]   672
B[13]   694
B[14]   684
B[15]   684
B[16]   696
B[17]   662
B[18]   710
B[19]   716
B[20]   766
B[21]   704
B[22]   662
B[23]   2068
B[24]   718
B[25]   680
B[26]   700
B[27]   670
B[28]   678
B[29]   678
B[30]   728
B[31]   682
B[32]   900
B[33]   664
B[34]   688
B[35]   770
B[36]   662
B[37]   694
B[38]   698
B[39]   682
```

```
B[39]   682
B[40]   678
B[41]   1828
B[42]   708
B[43]   678
B[44]   686
B[45]   678
B[46]   678
B[47]   662
B[48]   708
B[49]   682
B[50]   1188
B[51]   676
B[52]   1488
B[53]   684
B[54]   718
B[55]   710
B[56]   780
B[57]   708
B[58]   690
B[59]   1500
B[60]   688
B[61]   692
B[62]   686
B[63]   706
B[64]   672
B[65]   720
B[66]   728
B[67]   706
B[68]   666
B[69]   1048
B[70]   722
B[71]   702
B[72]   698
B[73]   684
B[74]   1130
B[75]   664
B[76]   740
B[77]   730
B[78]   688
B[79]   708
B[80]   688
B[81]   694
B[82]   684
```

```
B[82]   684
B[83]   708
B[84]   712
B[85]   706
B[86]   704
B[87]   2006
B[88]   696
B[89]   700
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$
```

Atomic Add Overhead in Histogram calculation with array size 1000000

```
----------------------------------------
Atomic Add times of each block
----------------------------------------
BLOCK   TIME
B[0]    698
B[1]    674
B[2]    762
B[3]    702
B[4]    702
B[5]    676
B[6]    682
B[7]    668
B[8]    706
B[9]    674
B[10]   714
B[11]   694
B[12]   660
B[13]   674
B[14]   692
B[15]   722
B[16]   670
B[17]   698
B[18]   690
B[19]   704
B[20]   696
B[21]   690
B[22]   740
B[23]   706
B[24]   712
B[25]   702
B[26]   726
B[27]   688
B[28]   682
B[29]   648
B[30]   680
B[31]   704
B[32]   680
B[33]   692
B[34]   690
B[35]   672
B[36]   692
B[37]   734
B[38]   676
B[39]   706
```

```
B[39]   706
B[40]   716
B[41]   712
B[42]   706
B[43]   736
B[44]   672
B[45]   716
B[46]   680
B[47]   670
B[48]   690
B[49]   680
B[50]   682
B[51]   724
B[52]   702
B[53]   696
B[54]   696
B[55]   764
B[56]   722
B[57]   718
B[58]   694
B[59]   730
B[60]   682
B[61]   728
B[62]   716
B[63]   706
B[64]   682
B[65]   720
B[66]   674
B[67]   686
B[68]   694
B[69]   748
B[70]   672
B[71]   686
B[72]   686
B[73]   714
B[74]   710
B[75]   678
B[76]   682
B[77]   674
B[78]   690
B[79]   702
B[80]   686
B[81]   706
B[82]   690
```

```
B[82]   690
B[83]   660
B[84]   698
B[85]   666
B[86]   728
B[87]   678
B[88]   714
B[89]   694
visu3975@ecee-gpu5:~/NVIDIA_GPU_Computing_SDK/C/bin/linux/release$
```