CME 433

Lab 6 : Graphic Processing Unit

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Verify of Matrix Multiplication work

figure 1 and figure 2 and figure 3 have proved that C programs from matrixMul and matrixmul_host work.

Solution

```
1383
            777
                  915
                         540
                               1426 \quad 1172
                                           1736
                                                     3265685 5411541 4558047
1793
      335
           1386
                  492
                         1211
                               1368
                                      567
                                            429
                                                     3876721
                                                              5694098
                                                                       4435141
                                                                                 5699425
649
      1421
            362
                   27
                         1782 \quad 1530
                                      862
                                           1123
                                                     2718184
                                                                        1930462
                                                                                 2191453
                                                              3453907
            1763 \quad 1926 / 67
690
      59
                               1135 \quad 1929 \quad 1802
                                                     3714757 5948052 6077093 6673652
```

Figure 1: 4x4 Matrix multiplication using symbolab tools (https://www.symbolab.com/)

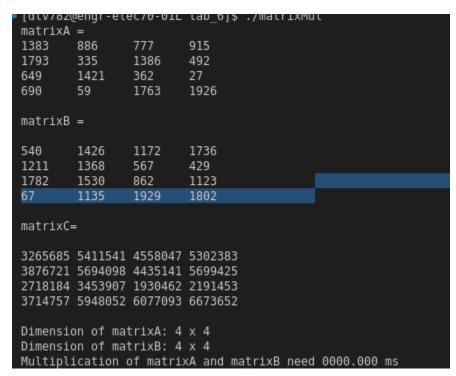


Figure 2: CPU 4x4 matrix multiplication using C program with OpenCL

```
[dtv782@engr-tau-21L lab 6]$ ./matrixmul host
 Initializing OpenCL device...
 Device: Intel(R) UHD Graphics 630 [0x9bc5]
 Running matrix multiplication for matrices A (4x4) and B (4x4) ...
 Matrix multiplication completed...
 Execution time in milliseconds = 0.013 ms
 matrixA =
                         915
         886
                 777
 1383
 1793
         335
                 1386
                         492
 649
         1421
                 362
                         27
 690
         59
                 1763
                         1926
 matrixB =
         1426
                 1172
                         1736
 540
         1368
                 567
                         429
 1211
         1530
 1782
                 862
                         1123
 67
         1135
                 1929
                         1802
 matrixC =
 3265685 5411541 4558047 5302383
 3876721 5694098 4435141 5699425
 2718184 3453907 1930462 2191453
 3714757 5948052 6077093 6673652
```

Figure 3: execute GPU 4 x 4 Matrix multiplication test run

Step 1 and Step 2 Comparison between CPU and GPU

Matrix Size	CPU Time execution (ms)	GPU Time execution(ms)
8 x 8	0.001	0.015
64 x 64	0.655	0.046
128 x 128	4.329	0.174
256 x 256	46.413	0.824
512 x 512	382.801	9.010

Observation:

The CPU works on synchronizing processing tasks through a clock and it works well on small to mid range mathematical equations. As we can see, the small matrix side makes the CPU run faster (4x4 or 8x8 matrix multiplication) than the GPU.

On the other hand, The CPU works better with massive parallel computing. It can handle high data throughput running parallel. Because of that, the execution time of GPU is significantly

faster than the CPU when we have more complex mathematical equations (larger side matrices in this case).

Additionally, GPU will require more power and more complexity and suitable for analytics and data science application which require large amounts of base data.

```
261703792
92
      254930416
                  257363664
45633248
          263308688 260652496
                                   262805584
      246170272 255832272 263511712
                                           26
56964432 260346400 257544992 259252304
      257647120 283849728 252515520
24
                                           25
67393120
            251116592 267699104
                                     267453008
      274928384 272082080 267171104
48
                                           24
70188928 262211888 250027008
                                     260498608
      277727648 259587200 240922464
71538624
           269476320 254372464
                                     257642016
      270041440 270252480 275255680
                                           25
Dimension of matrixA: 256 x 256
Dimension of matrixB: 256 x 256
Multiplication of matrixA and matrixB need 0046.413 ms
```

Figure 4: Time to execute CPU 256 x 256 Matrix multiplication

```
134961552
                  133766792
                               124421552
                                            1268
35555072
            127437904
                      136193376
                                     121349312
137733520
            141633600
                       135824144
                                     124733640
     130872160 143722368 135905312
                                            1348
42569200 152587808 127841304 135665728
76
     126319520 130875088 125734288 1367
36826656 128204440 135830224 142669680
     136669312 143784336 136769776
26619400 131250752 139404624 134286368
     134933040 135003792 122803456
                                           1334
36258096
        126279840 130432480 132762896
Dimension of matrixA: 128 x 128
Dimension of matrixB: 128 x 128
Multiplication of matrixA and matrixB need 0004.329 ms
```

Figure 5:Time to execute CPU 128 x 128 Matrix multiplication

2952008 6708524	18 55332260	65283744	64057816			
55743304	53927272	64771156	60862204 71			
4 6305253	62993332	2 60791984	58021224			
8864784 6543204	10 60221512	2 69048400	55971976			
6221688 6082678	4 64180680	59474096	63808344			
0037616 7164662	4 52378924	1 69089488	63544192			
61152556	63015720	64430468	66757116 72			
6 6863038	4 69250592	2 63094768	65919896			
1591872 7153567	⁷ 2 57971384	70963680	59085192			
0590976 7637296	6820534	4 61934292	63682628			
7251952 7216865	60956808	3 72027472	63959352			
Dimension of matrixA: 64 x 64						
Dimension of matrixB: 64 x 64						
Multiplication of matrixA and matrixB need 0000.655 ms						
	70 031 3 1 634		<u>"</u>			

Figure 6:Time to execute CPU 64 x 64 Matrix multiplication

matrixA =	Tigure 0. Time to execute of 0 of x of infatrix multiplication									
336 505 846 1729 1313 1857 124 1895 1582 545 814 1367 1434 364 43 1750 1087 808 1276 1178 1788 1584 1403 651 754 399 1932 1060 1676 1368 1739 12 226 586 94 1539 795 570 1434 378 1467 601 97 902 1317 492 652 756 1301 280 286 1441 1865 1689 444 619 440 729 31 117 97 1771 481 675 matrixC= 6317178 4172967 5263139 10603962 10508463 9772339 6532524 6809140 6263534 3742952 2854331 7400637 7683429 9143762 3433524 6649362 8227249 4692825 6889019 10068683 11622445 8833888 7878105 6435118 9785644 5453508 6746489 11495810 13277629 13277629 6291704 3510576 4196517 8737086 8953758 6727391 5872375 5162390 7117817 3858706 4763983 7216245 9432821 10616192 5826954 4781917 7169167 3665405 5865976 8524984 10251469 8395629 5461298 6051069	1383 649 540 1782 22 229 315	886 1421 1426 1530 1058 1373 370	362 1172 862 1069 421 413	27 1736 1123 167 919 1526	690 1211 67 1393 1784 91	59 1368 1135 456 537 980	1763 567 1929 1011 1198 1956	1926 429 1802 42 324 1873		
1582 545 814 1367 1434 364 43 1750 1087 808 1276 1178 1788 1584 1403 651 754 399 1932 1060 1676 1368 1739 12 226 586 94 1539 795 570 1434 378 1467 601 97 902 1317 492 652 756 1301 280 286 1441 1865 1689 444 619 440 729 31 117 97 1771 481 675 matrixC= 6317178 4172967 5263139 10603962 10508463 9772339 6532524 6809140 6263534 3742952 2854331 7400637 7683429 9143762 3433524 6649362 8227249 4692825 6889019 10068683 11622445 8833888 7878105 6435118 9785644 5453508 6746489 11495810 13277629 13813799 6008377 9922815 5286630 2922157 3032134 6937530 7334898 5148041 4602402 4116562 6291704 3510576 4196517 8737086 8953758 6727391 5872375 5162390 7117817 3858706 4763983 7216245 9432821 10616192 5826954 4781917 7169167 3665405 5865976 8524984 10251469 8395629 5461298 6051069	matrixB	=								
6263534 3742952 2854331 7400637 7683429 9143762 3433524 6649362 8227249 4692825 6889019 10068683 11622445 8833888 7878105 6435118 9785644 5453508 6746489 11495810 13277629 13813799 6008377 9922815 5286630 2922157 3032134 6937530 7334898 5148041 4602402 4116562 6291704 3510576 4196517 8737086 8953758 6727391 5872375 5162390 7117817 3858706 4763983 7216245 9432821 10616192 5826954 4781917 7169167 3665405 5865976 8524984 10251469 8395629 5461298 6051069	336 1582 1087 754 226 1467 1301 440	505 545 808 399 586 601 280 729	814 1276 1932 94 97 286	1367 1178 1060 1539 902 1441	1434 1788 1676 795 1317 1865	364 1584 1368 570 492 1689	43 1403 1739 1434 652 444	1750 651 12 378 756 619		
Dimension of matrixB: 8 x 8	6263534 8227249 9785644 5286630 6291704 7117817 7169167 Dimensio	3742952 4692825 5453508 2922157 3510576 3858706 3665405	2854331 6889019 6746489 3032134 4196517 4763983 5865976	7400637 1006868 11495810 6937530 8737086 7216245 8524984 x 8	7683429 3 0 7334898 8953758 9432821	9143762 1162244 1327762 5148041 6727391 1061619	3433524 5 9 4602402 5872375 2	6649362 8833888 7878105 13813799 4116562 5162390 5826954 4781917	6435118 6008377	9922815
Multiplication of matrixA and matrixB need 0000.001 ms										

Figure 7: Time to execute CPU 8 x 8 Matrix multiplication

```
502976064 526862752 511729536
36
     491415904 514069024
                            528455968
                                         5421096
24388352
           526167552 471730976
                                   506703328
     501800832 533881568 499098240
                                         5016791
98175904
           485078432 503754592
                                   530073600
     515498880 525567456 518990304
                                         4980643
        533041920 529792480 510289216
99241632
     498103968 506637824 526812800
                                         4913354
22516000
        509708256 514507680 499696160
50
     508074656 500102240 528620320
                                        4943256
12105984
       534294944 489571584 526888096
     497276640 507153664 487060864 5244188
24
       514294752 508685760 521223744
36077056
     513779552 489825248 533664640 4791619
72
99670240 501744768 503577760 495247424
     525991008 513434464 509824352 4985125
52
l4782816 505999968 512336512 514971104
20
     495619072 546967168 481617504
                                         5038643
L5936384 493057312 520115424 517446336
50
     523224320 504702848 508070752
                                         5506398
Dimension of matrixA: 512 x 512
Dimension of matrixB: 512 x 512
Multiplication of matrixA and matrixB need 0382.801 ms
```

Figure 8:Time to execute CPU 512 x 512 Matrix multiplication

```
[dtv782@engr-tau-21L lab_6]$ ./matrixmul_host
   Initializing OpenCL device...
   Device: Intel(R) UHD Graphics 630 [0x9bc5]
   Running matrix multiplication for matrices A (512x512) and B (512x512) ...
   Matrix multiplication completed...
   Execution time in milliseconds = 9.010 ms
```

Figure 9: time to execute GPU 512 x 512 Matrix multiplication

```
[dtv782@engr-tau-21L lab_6]$ ./matrixmul_host
Initializing OpenCL device...
Device: Intel(R) UHD Graphics 630 [0x9bc5]
Running matrix multiplication for matrices A (256x256) and B (256x256) ...
Matrix multiplication completed...

Execution time in milliseconds = 0.824 ms
```

Figure 10: time to execute GPU 256 x 256 Matrix multiplication

```
| [dtv/82@engr-tau-21L lab_b]$ ./matrixmul_nost
| Initializing OpenCL device...
| Device: Intel(R) UHD Graphics 630 [0x9bc5]
| Running matrix multiplication for matrices A (128x128) and B (128x128) ...
| Matrix multiplication completed...
| Execution time in milliseconds = 0.174 ms
```

Figure 11: time to execute GPU 128 x 128 Matrix multiplication

```
| [dtv782@engr-tau-21L lab_6]$ ./matrixmul_host
| Initializing OpenCL device...
| Device: Intel(R) UHD Graphics 630 [0x9bc5]
| Running matrix multiplication for matrices A (64x64) and B (64x64) ...
| Matrix multiplication completed...
| Execution time in milliseconds = 0.046 ms
```

Figure 12: time to execute GPU 64 x 64 Matrix multiplication

```
[dtv782@engr-tau-21L lab_6]$ ./matrixmul_host
Initializing OpenCL device...
Device: Intel(R) UHD Graphics 630 [0x9bc5]
Running matrix multiplication for matrices A (8x8) and B (8x8) ...
Matrix multiplication completed...
Execution time in milliseconds = 0.015 ms
matrixA =
                         915
1383
        886
                777
                                 1793
                                          335
                                                  1386
                                                           492
649
        1421
                362
                         27
                                 690
                                          59
                                                  1763
                                                           1926
540
        1426
                 1172
                         1736
                                 1211
                                          1368
                                                  567
                                                           429
1782
        1530
                862
                         1123
                                 67
                                          1135
                                                  1929
                                                           1802
        1058
                1069
                                 1393
                                          456
                                                  1011
                                                           42
22
                         167
229
        1373
                                  1784
                                          537
                                                  1198
                421
                         919
                                                           324
        370
                413
                         1526
                                                  1956
315
                                 91
                                          980
                                                           1873
                                          925
862
        1170
                996
                         1281
                                 305
                                                  1084
                                                           327
matrixB =
336
        505
                846
                         1729
                                 1313
                                          1857
                                                  124
                                                           1895
1582
        545
                814
                         1367
                                 1434
                                          364
                                                  43
                                                           1750
1087
        808
                1276
                         1178
                                 1788
                                          1584
                                                  1403
                                                           651
754
        399
                1932
                         1060
                                 1676
                                          1368
                                                  1739
226
        586
                94
                         1539
                                 795
                                          570
                                                  1434
                                                           378
                97
                                 1317
                                                           756
1467
        601
                         902
                                          492
                                                  652
1301
        280
                286
                         1441
                                 1865
                                          1689
                                                  444
                                                           619
440
        729
                         117
                                 97
                                          1771
                                                  481
                31
                                                           675
matrixC =
6317178 4172967 5263139 10603962
                                          10508463
                                                           9772339 6532524 6809140
6263534 3742952 2854331 7400637 7683429 9143762 3433524 6649362
8227249 4692825 6889019 10068683
                                          11622445
                                                           8833888 7878105 6435118
9785644 5453508 6746489 11495810
                                                                           6008377 9922815
                                          13277629
                                                           13813799
5286630 2922157 3032134 6937530 7334898 5148041 4602402 4116562
6291704 3510576 4196517 8737086 8953758 6727391 5872375 5162390
7117817 3858706 4763983 7216245 9432821 10616192
                                                           5826954 4781917
7169167 3665405 5865976 8524984 10251469
                                                  8395629 5461298 6051069
```

Figure 13: time to execute GPU 8 x 8 Matrix multiplication