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

$$\begin{pmatrix} 1383 & 886 & 777 & 915 \\ 1793 & 335 & 1386 & 492 \\ 649 & 1421 & 362 & 27 \\ 690 & 59 & 1763 & 1926 \end{pmatrix} \begin{pmatrix} 540 & 1426 & 1172 & 1736 \\ 1211 & 1368 & 567 & 429 \\ 1782 & 1530 & 862 & 1123 \\ 67 & 1135 & 1929 & 1802 \end{pmatrix} = \begin{pmatrix} 3265685 & 5411541 & 4558047 & 5302383 \\ 3876721 & 5694098 & 4435141 & 5699425 \\ 2718184 & 3453907 & 1930462 & 2191453 \\ 3714757 & 5948052 & 6077093 & 6673652 \end{pmatrix}$$

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

```
[dtv782@engr-etec70-01L tab_6]$ ./matrixMul
matrixA =
1383    886     777     915
1793    335     1386    492
649     1421    362     27
690     59      1763    1926

matrixB =

540     1426    1172    1736
1211    1368    567     429
1782    1530    862     1123
67      1135    1929    1802

matrixC=

3265685 5411541 4558047 5302383
3876721 5694098 4435141 5699425
2718184 3453907 1930462 2191453
3714757 5948052 6077093 6673652

Dimension of matrixA: 4 x 4
Dimension of matrixB: 4 x 4
Multiplication of matrixA and matrixB need 0000.000 ms
```
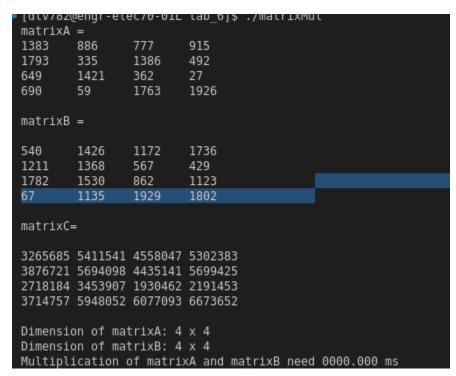
Figure 2: CPU 4x4 matrix multiplication using C program with OpenCL

```
● [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 =
1383    886     777     915
1793    335     1386    492
649     1421    362     27
690     59      1763    1926

matrixB =
540     1426    1172    1736
1211    1368    567     429
1782    1530    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.

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

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

```
 2952008 67085248        55332260         65283744        64057816
 55743304        53927272        64771156        60862204        71
 4        63052536        62993332        60791984        58021224
8864784 65432040        60221512        69048400        55971976
6221688 60826784        64180680        59474096        63808344
0037616 71646624        52378924        69089488        63544192
61152556        63015720        64430468        66757116        72
6        68630384        69250592        63094768        65919896
1591872 71535672        57971384        70963680        59085192
0590976 76372968        68205344        61934292        63682628
7251952 72168656        60956808        72027472        63959352

 Dimension of matrixA: 64 x 64
 Dimension of matrixB: 64 x 64
 Multiplication of matrixA and matrixB need 0000.655 ms
```

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

```
matrixA =
1383        886        777        915        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
22        1058        1069        167        1393        456        1011        42
229        1373        421        919        1784        537        1198        324
315        370        413        1526        91        980        1956        1873
862        1170        996        1281        305        925        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        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

Dimension of matrixA: 8 x 8
Dimension of matrixB: 8 x 8
Multiplication of matrixA and matrixB need 0000.001 ms
```

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

```
35685504          502976064          526862752          511729536
36       491415904          514069024          528455968          542109(
24388352          526167552          471730976          506703328
08       501800832          533881568          499098240          501679(
98175904          485078432          503754592          530073600
50       515498880          525567456          518990304          498064:
99241632          533041920          529792480          510289216
08       498103968          506637824          526812800          491335(
22516000          509708256          514507680          499696160
50       508074656          500102240          528620320          494325(
12105984          534294944          489571584          526888096
24       497276640          507153664          487060864          524418(
36077056          514294752          508685760          521223744
72       513779552          489825248          533664640          479161(
99670240          501744768          503577760          495247424
62       525991008          513434464          509824352          498512!
14782816          505999968          512336512          514971104
20       495619072          546967168          481617504          503864:
15936384          493057312          520115424          517446336
50       523224320          504702848          508070752          550639(

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

```
[dtv782@engr-tau-21L lab_6]$ ./matrixmul_host
 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 =
1383     886     777     915     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
22       1058    1069    167     1393    456     1011    42
229      1373    421     919     1784    537     1198    324
315      370     413     1526    91      980     1956    1873
862      1170    996     1281    305     925     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    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
```

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