**Parcial 1 HPC: Multiplicación de matrices.**

En el siguiente trabajo se pretende mostrar el rendimiento computacional de la operación de multiplicar matrices, utilizando una versión secuencial, otra en paralelo y una versión en paralelo mejorada utilizando memoria compartida.

Se mostrarán gráficas de tiempo y aceleración en varias muestras de datos para el correcto análisis de todo el experimento.

**1.Tablas**

**1.1.Tabla secuencial**

Para el código secuencial usaremos una misma muestra de datos para comparar con todas las demás muestras.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Secuencial** | | | | | | | |
| **Tamaño de la matriz** | | **Tiempo** | | | | | **Promedio** |
| **N** | **M** |
| 4 | 8 | 0.000003 | 0.000001 | 0.000002 | 0.000003 | 0.000002 | 0.000002 |
| 8 | 16 | 0.000007 | 0.000008 | 0.000004 | 0.000008 | 0.000004 | 0.000007 |
| 16 | 32 | 0.000022 | 0.000053 | 0.000022 | 0.000025 | 0.000053 | 0.000025 |
| 32 | 64 | 0.000427 | 0.000425 | 0.000175 | 0.000428 | 0.000201 | 0.000425 |
| 64 | 128 | 0.001355 | 0.001962 | 0.001393 | 0.001354 | 0.002312 | 0.001393 |
| 128 | 256 | 0.018135 | 0.012748 | 0.017365 | 0.016294 | 0.018297 | 0.017365 |
| 512 | 1024 | 0.71641 | 0.719023 | 0.713875 | 0.714625 | 0.71843 | 0.71641 |
| 1024 | 1024 | 3.322625 | 3.310955 | 3.323135 | 3.306846 | 3.295315 | 3.310955 |

**1.2.Tablas 4 x 4**

Para empezar se toman muestrascon código secuencial y luego con código utilizando GPU y GPU con memoria compartida con un tamaño de bloque de 4 x 4, posteriormente haremos un vs entre los tiempos para hallar la aceleración.

**Tiempos:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **TAMAÑO 4 X 4** | | | | | | | |
| **Paralelo sin tiling** | | | | | | | |
| **Tamaño de la matriz** | | **Tiempo** | | | | | **Promedio** |
| **N** | **M** |
| **4** | **8** | **0.000058** | **0.000057** | **0.000058** | **0.000059** | **0.000058** | **0.000058** |
| **8** | **16** | **0.000063** | **0.00006** | **0.000061** | **0.000064** | **0.000062** | **0.000062** |
| **16** | **32** | **0.000068** | **0.000066** | **0.000066** | **0.000067** | **0.00007** | **0.000067** |
| **32** | **64** | **0.000083** | **0.000083** | **0.00008** | **0.000079** | **0.00008** | **0.00008** |
| **64** | **128** | **0.000154** | **0.000154** | **0.000151** | **0.00015** | **0.000155** | **0.000154** |
| **128** | **256** | **0.000512** | **0.000514** | **0.000506** | **0.000509** | **0.000516** | **0.000512** |
| **512** | **1024** | **0.02439** | **0.024395** | **0.024371** | **0.024351** | **0.024382** | **0.024382** |
| **1024** | **1024** | **0.09565** | **0.095705** | **0.095728** | **0.095879** | **0.095659** | **0.095705** |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **TAMAÑO 4 X 4** | | | | | | | |
| **Paralelo con tiling** | | | | | | | |
| **Tamaño de la matriz** | | **Tiempo** | | | | | **Promedio** |
| **N** | **M** |
| **4** | **8** | **0.000063** | **0.000065** | **0.000058** | **0.000059** | **0.00006** | **0.00006** |
| **8** | **16** | **0.000058** | **0.000059** | **0.000063** | **0.00006** | **0.000062** | **0.00006** |
| **16** | **32** | **0.000059** | **0.00006** | **0.000061** | **0.000063** | **0.00006** | **0.00006** |
| **32** | **64** | **0.000065** | **0.000065** | **0.000066** | **0.000067** | **0.000069** | **0.000066** |
| **64** | **128** | **0.000102** | **0.000104** | **0.000102** | **0.000106** | **0.000102** | **0.000102** |
| **128** | **256** | **0.000288** | **0.000289** | **0.000287** | **0.00029** | **0.000291** | **0.000289** |
| **512** | **1024** | **0.010195** | **0.010194** | **0.010179** | **0.010206** | **0.010185** | **0.010194** |
| **1024** | **1024** | **0.038154** | **0.038131** | **0.038107** | **0.038138** | **0.038063** | **0.038131** |

**Aceleración:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Aceleración con tamaño 4x4** | | | | | | | |
|
| **Tamaño Matriz** | | **Tiempo secuencial** | **Tiempo sin tiling** | **Tiempo con tiling** | **CPU vs GPU** | **CPU vs GPU Tiling** | **GPU vs GPU Tiling** |
| **N** | **M** |
| **4** | **8** | **0.000002** | **0.000058** | **0.00006** | **0.03448275862** | **0.03333333333** | **0.9666666667** |
| **8** | **16** | **0.000007** | **0.000062** | **0.00006** | **0.1129032258** | **0.1166666667** | **1.033333333** |
| **16** | **32** | **0.000025** | **0.000067** | **0.00006** | **0.3731343284** | **0.4166666667** | **1.116666667** |
| **32** | **64** | **0.000425** | **0.00008** | **0.000066** | **5.3125** | **6.439393939** | **1.212121212** |
| **64** | **128** | **0.001393** | **0.000154** | **0.000102** | **9.045454545** | **13.65686275** | **1.509803922** |
| **128** | **256** | **0.017365** | **0.000512** | **0.000289** | **33.91601563** | **60.08650519** | **1.771626298** |
| **512** | **1024** | **0.71641** | **0.024382** | **0.010194** | **29.38274137** | **70.27761428** | **2.391799098** |
| **1024** | **1024** | **3.310955** | **0.095705** | **0.038131** | **34.59542344** | **86.8310561** | **2.509900081** |

**1.3.Tablas 16 x 16**

Para empezar se toman muestrascon código secuencial y luego con código utilizando GPU y GPU con memoria compartida con un tamaño de bloque de 16x16, posteriormente haremos un vs entre los tiempos para hallar la aceleración.

**Tiempos:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **TAMAÑO 16 X 16** | | | | | | | |
| **Paralelo sin tiling** | | | | | | | |
| **Tamaño de la matriz** | | **Tiempo** | | | | | **Promedio** |
| **N** | **M** |
| 4 | 8 | 0.000061 | 0.000062 | 0.000058 | 0.000062 | 0.000058 | 0.000061 |
| 8 | 16 | 0.000063 | 0.000063 | 0.000061 | 0.00006 | 0.000062 | 0.000062 |
| 16 | 32 | 0.000071 | 0.000066 | 0.000069 | 0.000066 | 0.00007 | 0.000069 |
| 32 | 64 | 0.000077 | 0.000079 | 0.000078 | 0.00008 | 0.00008 | 0.000079 |
| 64 | 128 | 0.000115 | 0.000122 | 0.000117 | 0.000115 | 0.000117 | 0.000117 |
| 128 | 256 | 0.000267 | 0.000262 | 0.000267 | 0.000258 | 0.00026 | 0.000262 |
| 512 | 1024 | 0.006994 | 0.006953 | 0.006942 | 0.00698 | 0.007052 | 0.00698 |
| 1024 | 1024 | 0.025051 | 0.025082 | 0.024987 | 0.025056 | 0.025251 | 0.025056 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **TAMAÑO 16 X 16** | | | | | | | |
| **Paralelo con tiling** | | | | | | | |
| **Tamaño de la matriz** | | **Tiempo** | | | | | **Promedio** |
| **N** | **M** |
| **4** | **8** | **0.000058** | **0.000057** | **0.000062** | **0.00006** | **0.000061** | **0.00006** |
| **8** | **16** | **0.000061** | **0.000057** | **0.000057** | **0.00006** | **0.000058** | **0.000058** |
| **16** | **32** | **0.000063** | **0.000064** | **0.00006** | **0.00006** | **0.000068** | **0.000063** |
| **32** | **64** | **0.000066** | **0.000068** | **0.00007** | **0.000071** | **0.000069** | **0.000069** |
| **64** | **128** | **0.000094** | **0.000092** | **0.000092** | **0.000094** | **0.000091** | **0.000092** |
| **128** | **256** | **0.000195** | **0.000191** | **0.000196** | **0.000195** | **0.000195** | **0.000195** |
| **512** | **1024** | **0.003702** | **0.003697** | **0.003715** | **0.003703** | **0.003709** | **0.003703** |
| **1024** | **1024** | **0.012188** | **0.012165** | **0.012204** | **0.012241** | **0.012145** | **0.012188** |

**Aceleración:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Aceleración con tamaño 16x16** | | | | | | | |
|
| **Tamaño Matriz** | | **Tiempo secuencial** | **Tiempo sin tiling** | **Tiempo con tiling** | **CPU vs GPU** | **CPU vs GPU Tiling** | **GPU vs GPU Tiling** |
| **N** | **M** |
| **4** | **8** | **0.000002** | **0.000061** | **0.00006** | **0.03278688525** | **0.03333333333** | **1.016666667** |
| **8** | **16** | **0.000007** | **0.000062** | **0.000058** | **0.1129032258** | **0.1206896552** | **1.068965517** |
| **16** | **32** | **0.000025** | **0.000069** | **0.000063** | **0.3623188406** | **0.3968253968** | **1.095238095** |
| **32** | **64** | **0.000425** | **0.000079** | **0.000069** | **5.379746835** | **6.15942029** | **1.144927536** |
| **64** | **128** | **0.001393** | **0.000117** | **0.000092** | **11.90598291** | **15.14130435** | **1.27173913** |
| **128** | **256** | **0.017365** | **0.000262** | **0.000195** | **66.27862595** | **89.05128205** | **1.343589744** |
| **512** | **1024** | **0.71641** | **0.00698** | **0.003703** | **102.6375358** | **193.4674588** | **1.884958142** |
| **1024** | **1024** | **3.310955** | **0.025056** | **0.012188** | **132.1422015** | **271.6569577** | **2.055792583** |

**1.3.Tablas 32 x 32**

Para empezar se toman muestrascon código secuencial y luego con código utilizando GPU y GPU con memoria compartida con un tamaño de bloque de 32x32, posteriormente haremos un vs entre los tiempos para hallar la aceleración.

**Tiempo:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **TAMAÑO 32 X 32** | | | | | | | |
| **Paralelo sin tiling** | | | | | | | |
| **Tamaño de la matriz** | | **Tiempo** | | | | | **Promedio** |
| **N** | **M** |
| **4** | **8** | **0.000059** | **0.000062** | **0.000068** | **0.000061** | **0.000059** | **0.000061** |
| **8** | **16** | **0.000083** | **0.000064** | **0.000065** | **0.000061** | **0.000067** | **0.000065** |
| **16** | **32** | **0.000076** | **0.000069** | **0.00007** | **0.000072** | **0.000076** | **0.000072** |
| **32** | **64** | **0.000089** | **0.00009** | **0.000088** | **0.000086** | **0.000086** | **0.000088** |
| **64** | **128** | **0.000131** | **0.000141** | **0.000141** | **0.000132** | **0.000137** | **0.000137** |
| **128** | **256** | **0.000303** | **0.000302** | **0.000301** | **0.000301** | **0.000307** | **0.000302** |
| **512** | **1024** | **0.006904** | **0.006928** | **0.007068** | **0.007028** | **0.006876** | **0.006928** |
| **1024** | **1024** | **0.023938** | **0.024412** | **0.024367** | **0.02454** | **0.024276** | **0.024367** |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **TAMAÑO 32 X 32** | | | | | | | |
| **Paralelo con tiling** | | | | | | | |
| **Tamaño de la matriz** | | **Tiempo** | | | | | **Promedio** |
| **N** | **M** |
| **4** | **8** | **0.000069** | **0.000062** | **0.000061** | **0.000061** | **0.000064** | **0.000062** |
| **8** | **16** | **0.000061** | **0.000083** | **0.000065** | **0.000073** | **0.000067** | **0.000067** |
| **16** | **32** | **0.000067** | **0.000067** | **0.000066** | **0.00009** | **0.000063** | **0.000067** |
| **32** | **64** | **0.000071** | **0.000072** | **0.000083** | **0.000074** | **0.000089** | **0.000074** |
| **64** | **128** | **0.000098** | **0.000098** | **0.0001** | **0.000129** | **0.000101** | **0.0001** |
| **128** | **256** | **0.000222** | **0.000222** | **0.000211** | **0.000209** | **0.000225** | **0.000222** |
| **512** | **1024** | **0.00339** | **0.003394** | **0.003377** | **0.003377** | **0.00338** | **0.00338** |
| **1024** | **1024** | **0.010762** | **0.010701** | **0.010699** | **0.01074** | **0.010737** | **0.010737** |

**Aceleración:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Aceleración con tamaño 32x32** | | | | | | | |
|
| **Tamaño Matriz** | | **Tiempo secuencial** | **Tiempo sin tiling** | **Tiempo con tiling** | **CPU vs GPU** | **CPU vs GPU Tiling** | **GPU vs GPU Tiling** |
| **N** | **M** |
| **4** | **8** | **0.000002** | **0.000061** | **0.000062** | **0.03278688525** | **0.03225806452** | **0.9838709677** |
| **8** | **16** | **0.000007** | **0.000065** | **0.000067** | **0.1076923077** | **0.1044776119** | **0.9701492537** |
| **16** | **32** | **0.000025** | **0.000072** | **0.000067** | **0.3472222222** | **0.3731343284** | **1.074626866** |
| **32** | **64** | **0.000425** | **0.000088** | **0.000074** | **4.829545455** | **5.743243243** | **1.189189189** |
| **64** | **128** | **0.001393** | **0.000137** | **0.0001** | **10.16788321** | **13.93** | **1.37** |
| **128** | **256** | **0.017365** | **0.000302** | **0.000222** | **57.5** | **78.22072072** | **1.36036036** |
| **512** | **1024** | **0.71641** | **0.006928** | **0.00338** | **103.4079099** | **211.9556213** | **2.049704142** |
| **1024** | **1024** | **3.310955** | **0.024367** | **0.010737** | **135.8786474** | **308.368725** | **2.269442116** |

**2.Conclusiones**

* **Al igual que la suma de vectores, la multiplicación de matrices de forma secuencial es más efectiva cuando no hay una gran cantidad de datos.**
* **Al apreciar los tiempos de ejecución de la multiplicación de matrices de forma paralela (con y sin tiling), podemos comprobar una mejoría en el desempeño de la multiplicación de matrices con tiling en comparación con la multiplicación sin tiling.**
* **Podemos apreciar que con una gran cantidad de datos, la multiplicación secuencial demora bastante, llegando incluso a tiempos de ejecución 3 segundos (3s).**