# Dataparallel Programming on GPUs

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# Inhaltsverzeichnis

# Aufgabenstellung

- Möglichst effiziente Implementierung einer Matrixmultiplikation in row-major und column-major Format
- Quadratische Matrizen der Dimension $32 * k, k \in \{1, 2, 4, \ldots, 128\}$

# Naiver Algoritmus

- C-Code für die CPU
- Sequentielle Ausführung

Listing 1: Matrixmultiplication in C

```
int i,j,k;

for( i = 0, i<Ndim; i++){
   for( j = 0, j<Mdim;j++){
      for( k = 0; k<Pdim; k++){
         C[i*Ndim+j] += A[i*Ndim+k] * B[k*Pdim+j];
      }
   }
}
```

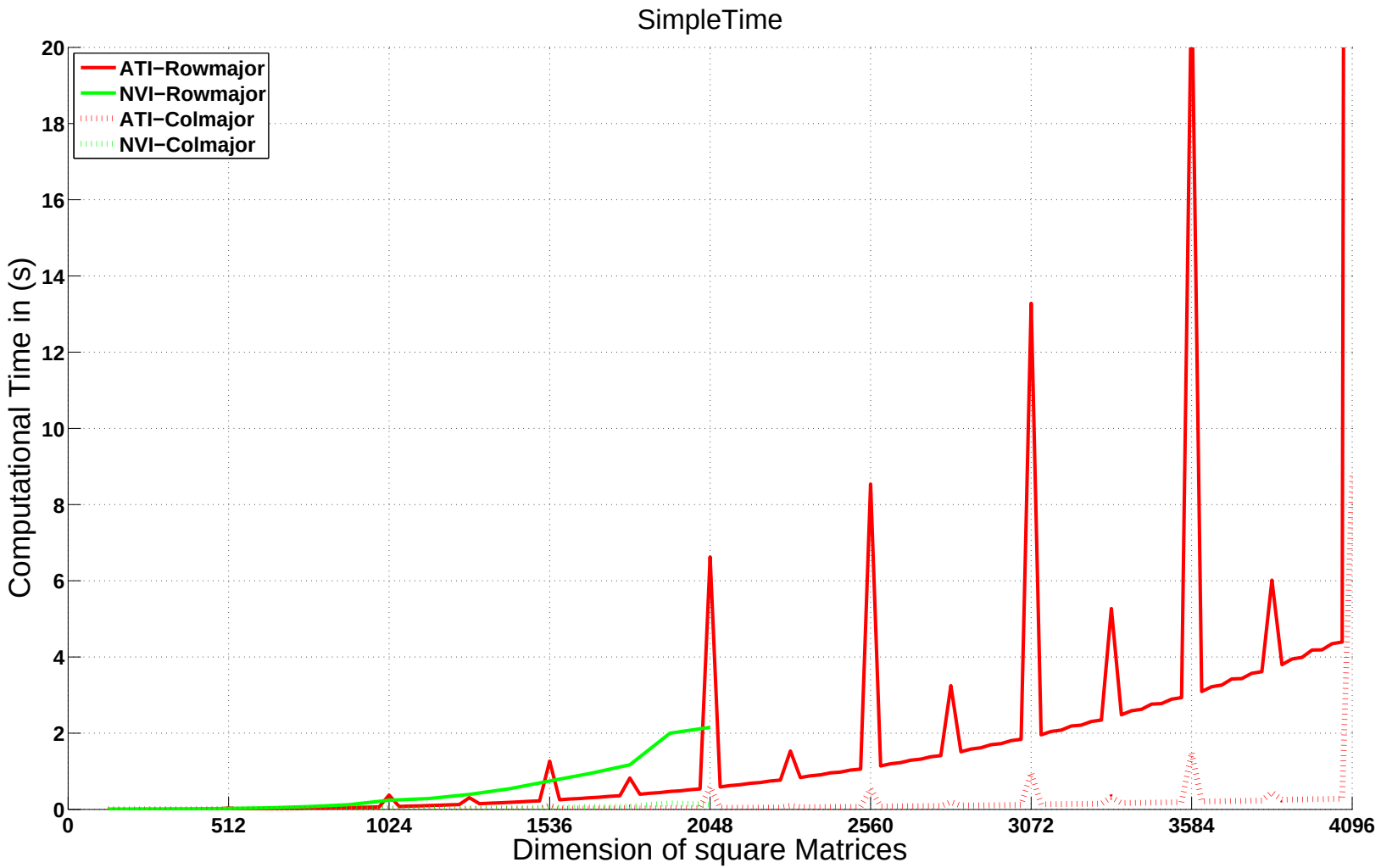
# Einfache Implementierung

## Einfache Implementierung in OpenCL

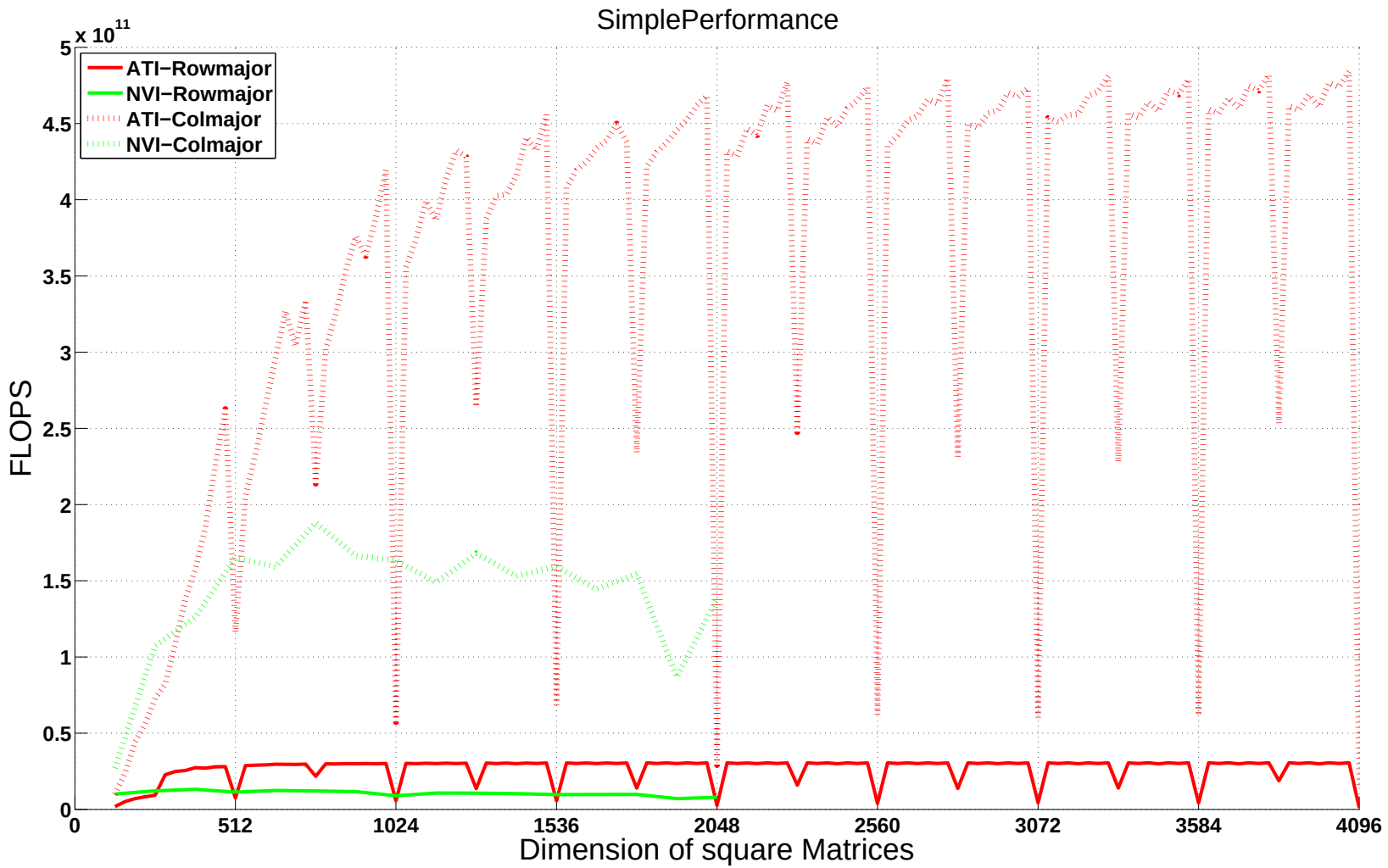
Listing 2: Einfachster Code in OpenCL

```
int i,j,k;
i = global_id(0);
j = global_id(1);
  for(k=0; k<Pdim; k++){
    C[i*Ndim+j] += A[i*Ndim+k] * B[k*Pdim+j];
  }
```

# Laufzeit


SimpleTime
ATI−Rowmajor
NVI−Rowmajor
ATI−Colmajor
NVI−Colmajor
Computational Time in (s)
Dimension of square Matrices
0
2
4
6
8
10
12
14
16
18
20
0
512
1024
1536
2048
2560
3072
3584
4096

# Performance



# NVIDIA-Template

- Zerlegung der Matrix in Blöcken
- Verwendung von lokalem Speicher

Listing 3: NVIDIA-Snippet

```
int bx = get_group_id(0); // Blockindex x
int by = get_group_id(1); // Blockindex y
int tx = get_local_id(0); // Threadindex x
int ty = get_local_id(1); // Threadindey y
```

## Listing 4: NVIDIA-Snippet(2)

```
__local T As[16][16];__local T Bs[16][16]; T Csub =
    0.0f;
for (int a = aBegin, b = bBegin; a <= aEnd; a += aStep
    , b += bStep){
As[ty][tx] = A[a + ty + hA * tx];
Bs[ty][tx] = B[b + ty + hA * tx];
barrier(CLK_LOCAL_MEM_FENCE);
for (int k = 0; k < 16; ++k)Csub += As[ty][k] * Bs[k][
    tx];
}
     barrier(CLK_LOCAL_MEM_FENCE);
}
int c = 16 * ( by + hA* bx):
C[c + hA * tx + ty] = Csub;
```

# Optimierung

- Anzahl der Threadblocks werden verringert, Anzahl der Blocks bleiben
- Halb so viele Threads, jedoch doppelt so viel Arbeit pro Thread

Listing 5: Optimized Code in OpenCL

```
T Csub[2] = {0,0};
 __local T As[BLOCK_SIZE][BLOCK_SIZE];
 __local T Bs[BLOCK_SIZE][BLOCK_SIZE];
for (int a = aBegin, b = bBegin; a <= aEnd;a += aStep,
     b+=bStep){
AS(ty, tx) = A[a + wA * ty + tx];
BS(ty, tx) = B[b + wB * ty + tx];
AS(ty+16, tx) = A[a + wA * (ty+16) + tx];
BS(ty+16, tx) = B[b + wB * (ty+16) + tx];
barrier(CLK_LOCAL_MEM_FENCE); // sync threads
}
```

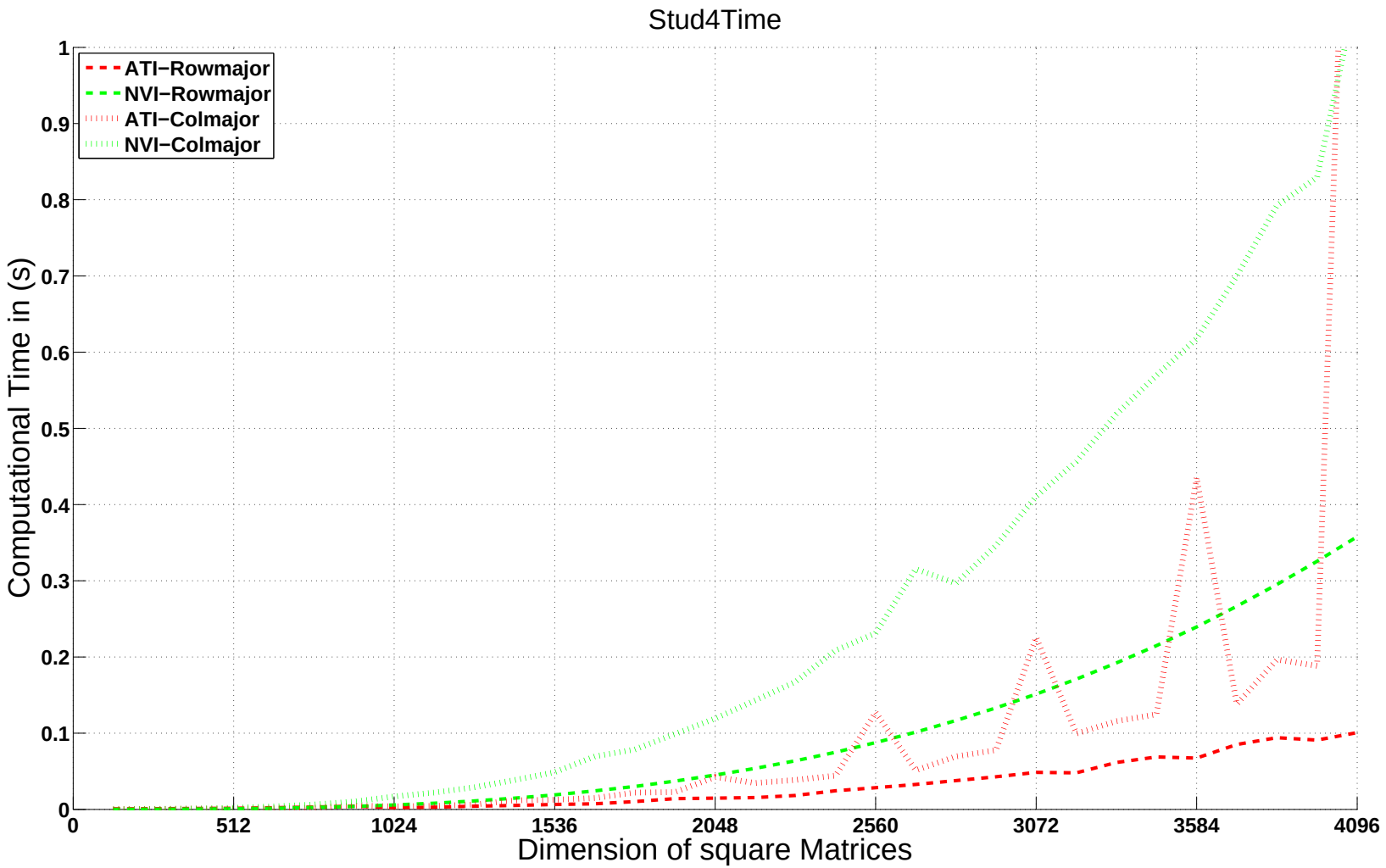
# Optimierung

Listing 6: innere Schleife und Output

```
for (int k = 0; k < BLOCK_SIZE; ++k){
Csub[0] += AS(ty, k) * BS(k, tx);
Csub[1] += AS(ty+16, k) * BS(k, tx);
}
barrier(CLK_LOCAL_MEM_FENCE); // sync threads
}
int c = wB * BLOCK_SIZE * by + BLOCK_SIZE * bx;
C[c + wB * ty + tx] = Csub[0];
C[c + wB * (ty+16) + tx] = Csub[1];
```

- Daten aus dem lokalen Speicher werden wiederverwendet
- Weniger Threads pro Block ermöglich Überlappung von Speicherzugriff mit Arithmetik

# Laufzeitmessung auf ATI und NVIDIA



# Performancemessung auf ATI und NVIDIA

# Vergleich

| | Simple Perf. | Opt. Perf. | Peak Perf. | S/P | O/P |
|---|---|---|---|---|---|
| AMD RM | $3.056e+10$ | $1.372e+12$ | $3.79e+12$ | 0.8 | 36.23 |
| AMD CM | $4.843e+11$ | $7.588e+11$ | $3.79e+12$ | 12.78 | 20.03 |
| Nvidia RM | $1.319e+10$ | $3.845e+11$ | $1.03e+12$ | 1.28 | 37.33 |
| Nvidia CM | $1.881e+11$ | $1.506e+11$ | $1.03e+12$ | 18.26 | 14.63 |

# Begründung der Ergebnisse und mögl. Verbesserungen

- Vektorarithmetik (float4)
- Image-Objekte

# Quellen


University of Bristol

Optimizing OpenCL performance

http://www.cs.bris.ac.uk/home/simonm/workshops/OpenCL_lecture3.pdf

NVIDIA

OpenCL SDK Code Samples

https://developer.nvidia.com/opencl

Vasily Volkov (UC Berkeley , September 22, 2010)

Better Performance at Lower Occupancy

http://www.cs.berkeley.edu/~volkov/volkov10-GTC.pdf

Vielen Dank für eure Aufmerksamkeit!