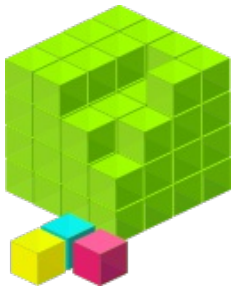
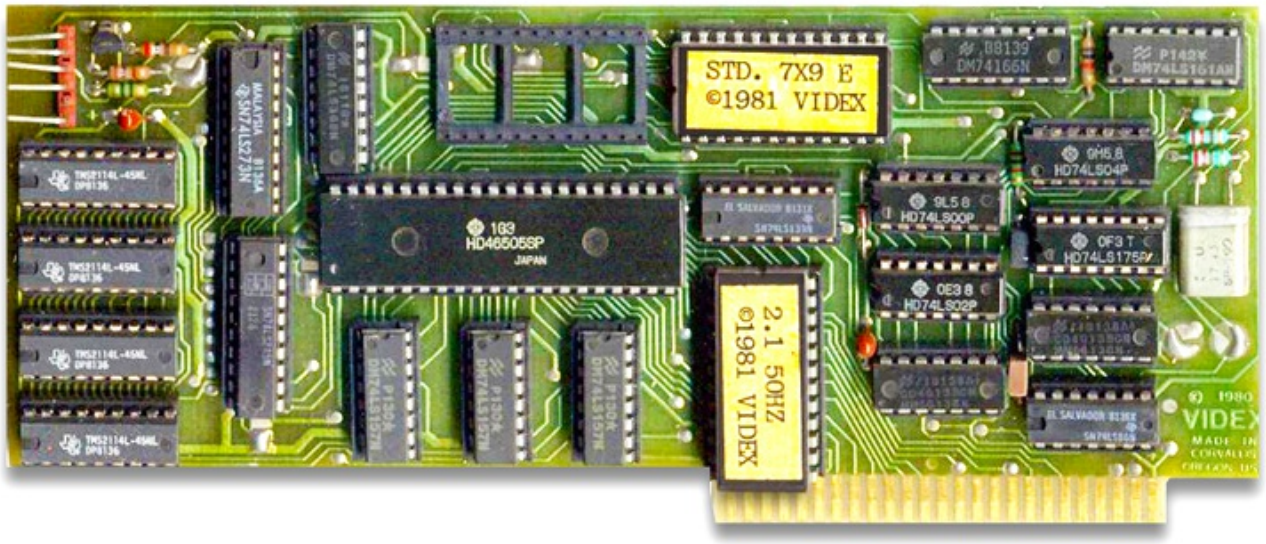
GPU Programmierung mit CUDA

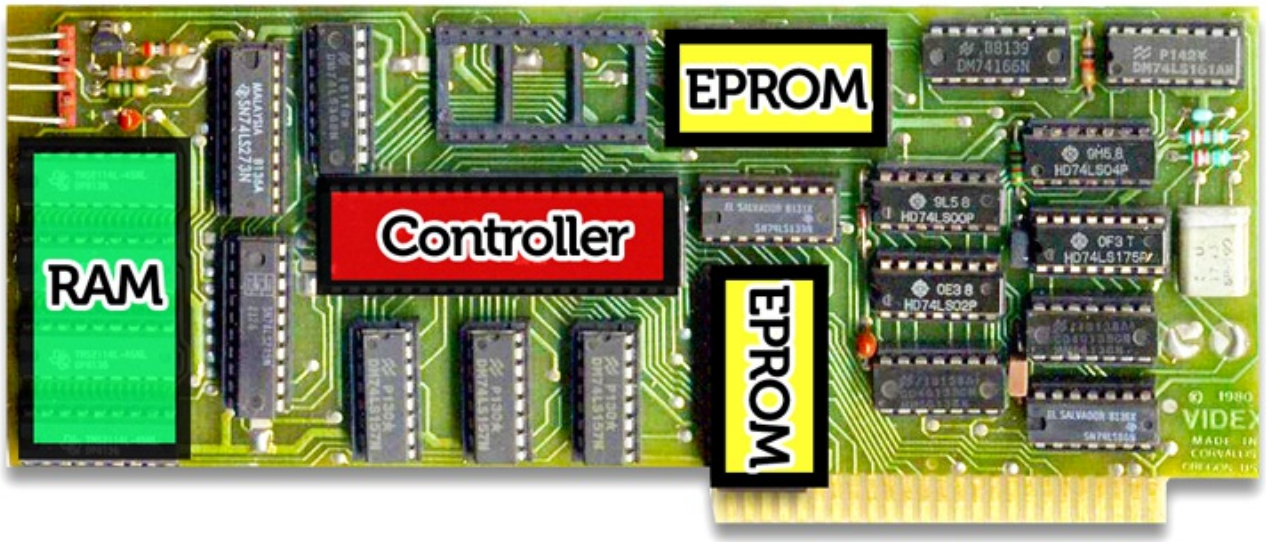
Matthias Endler



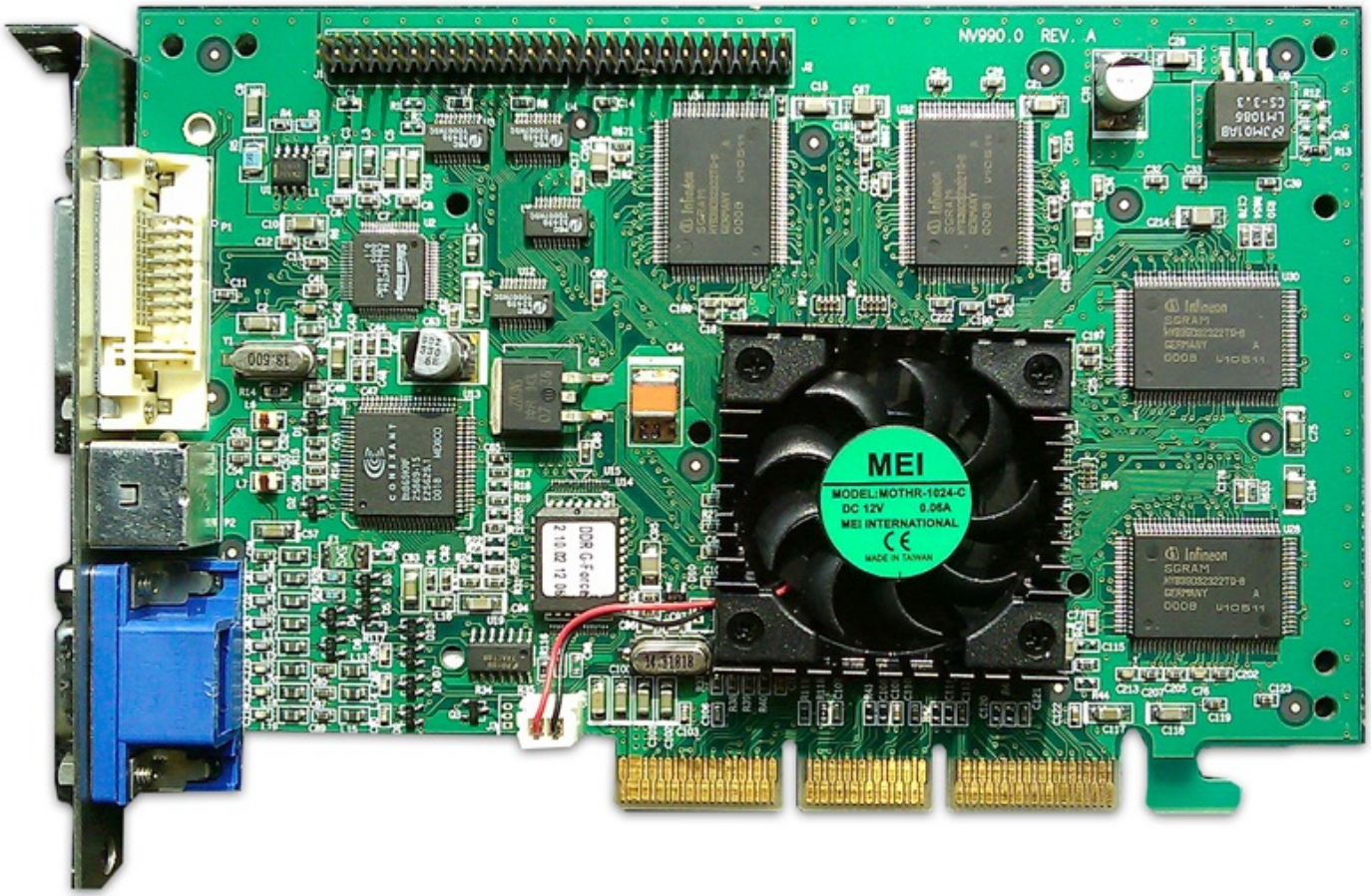
Apple II, 1977



Videx Videoterm, 1981

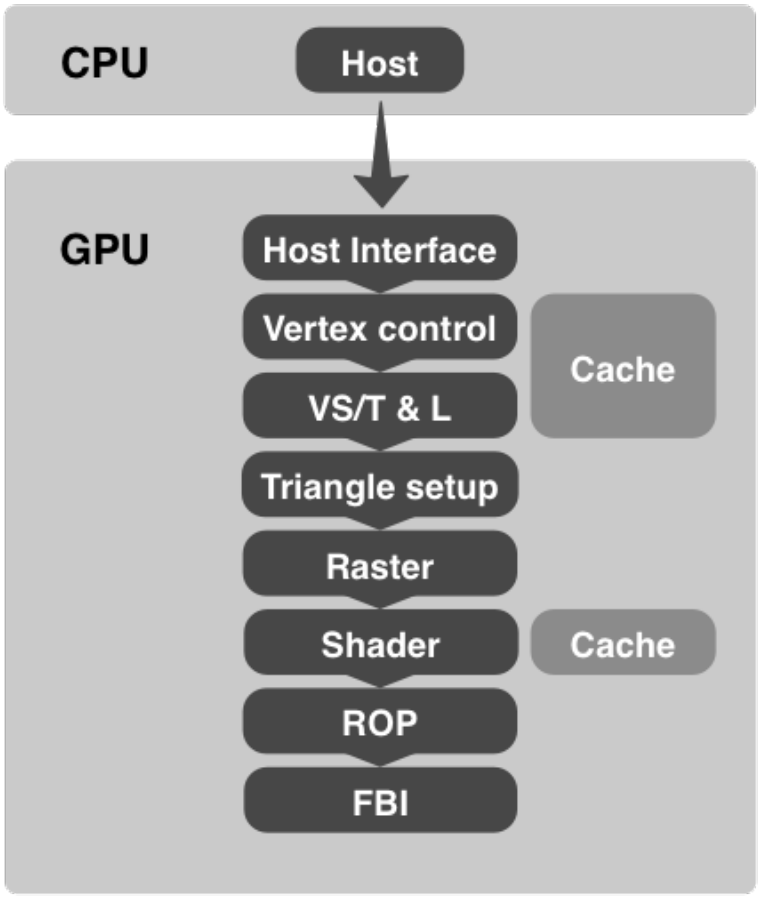


Videx Videoterm, 1981

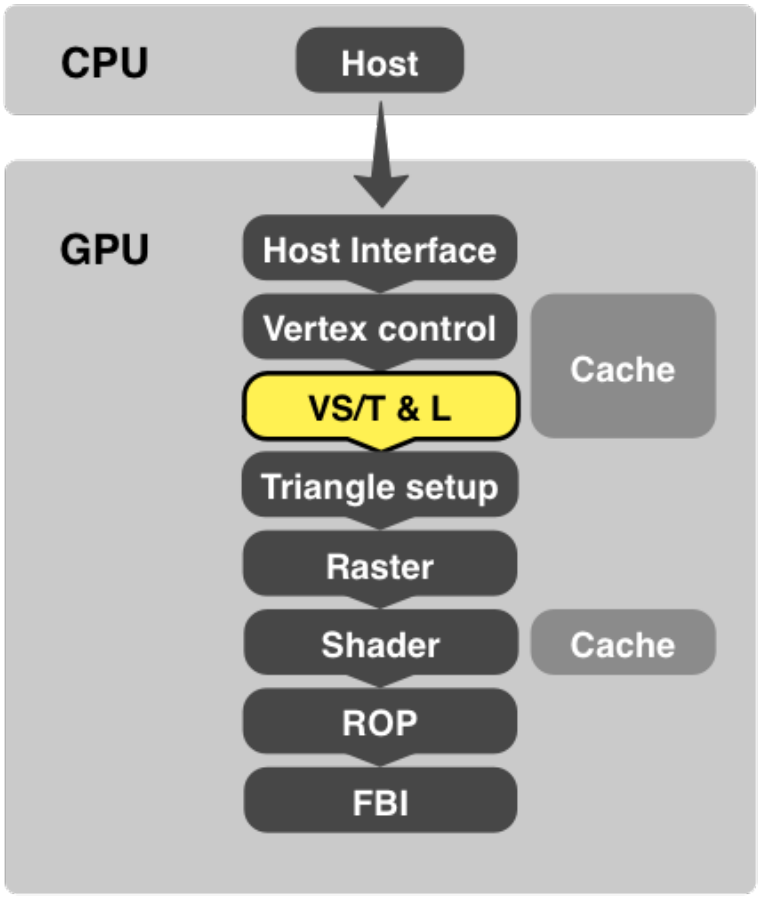


VisionTek Geforce 256, 1999

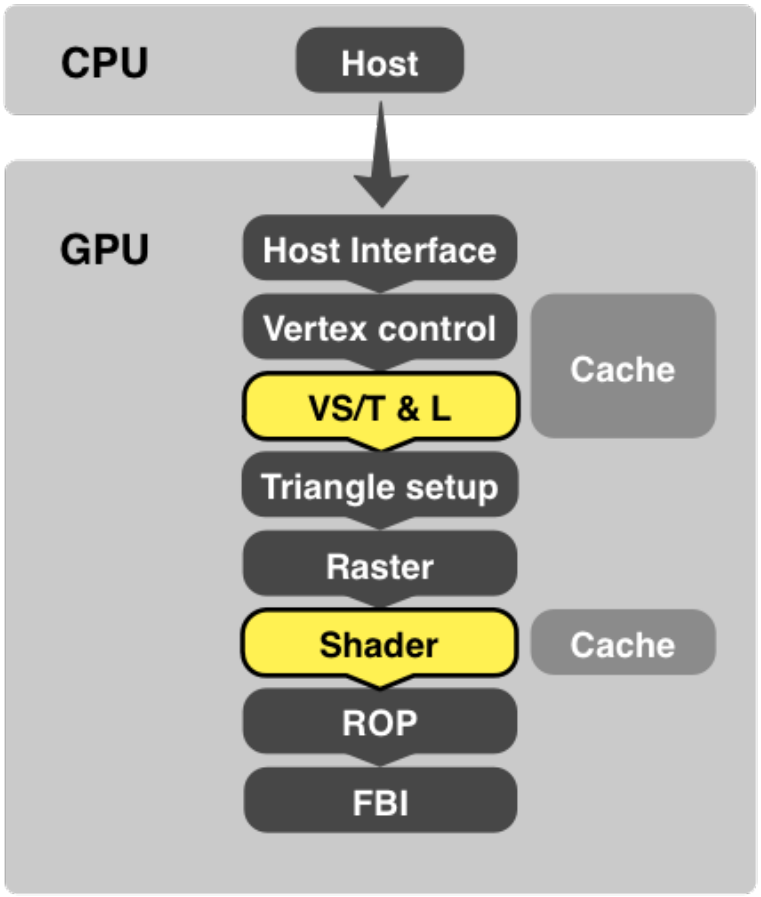
Fixed-function pipeline



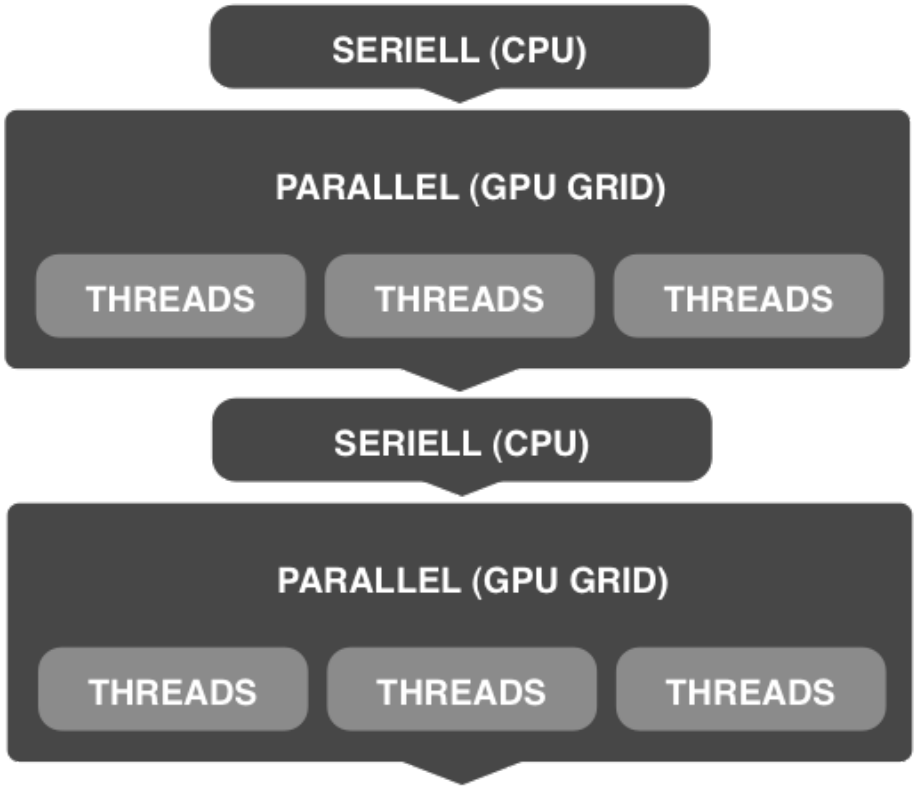
Fixed-function pipeline



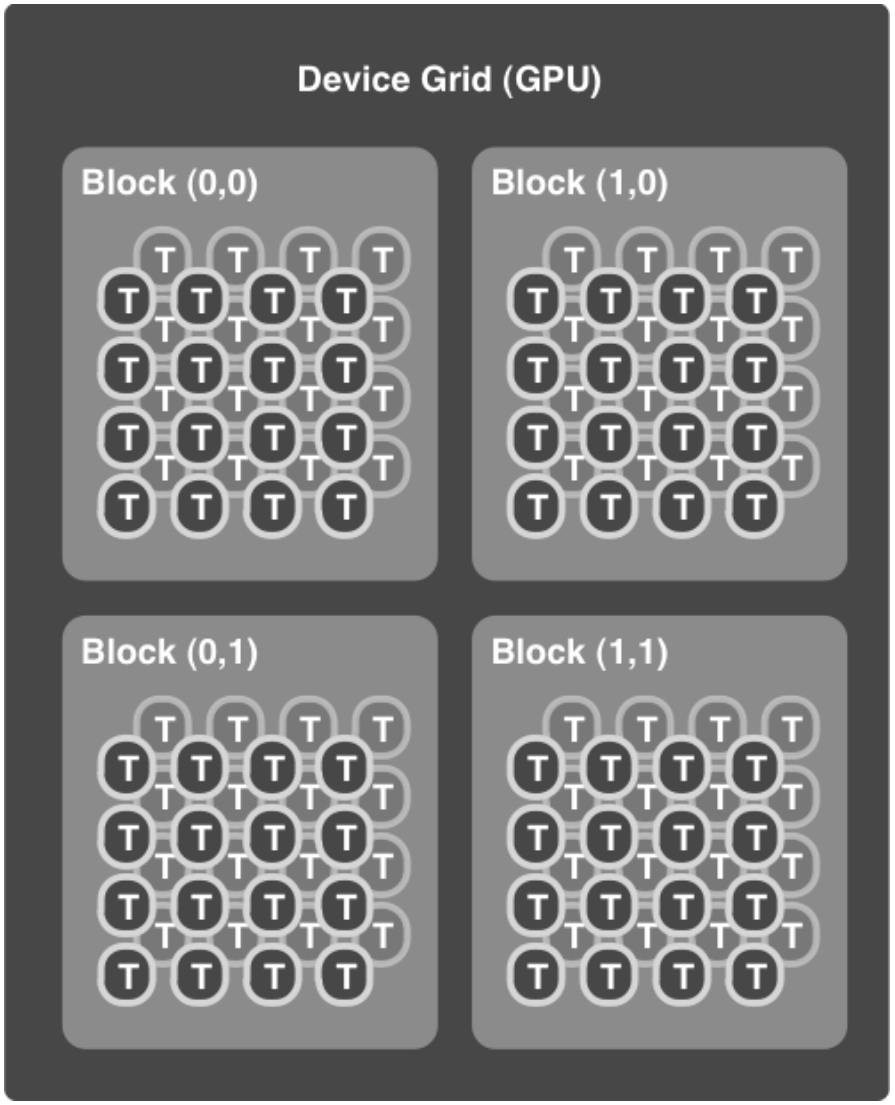
Fixed-function pipeline



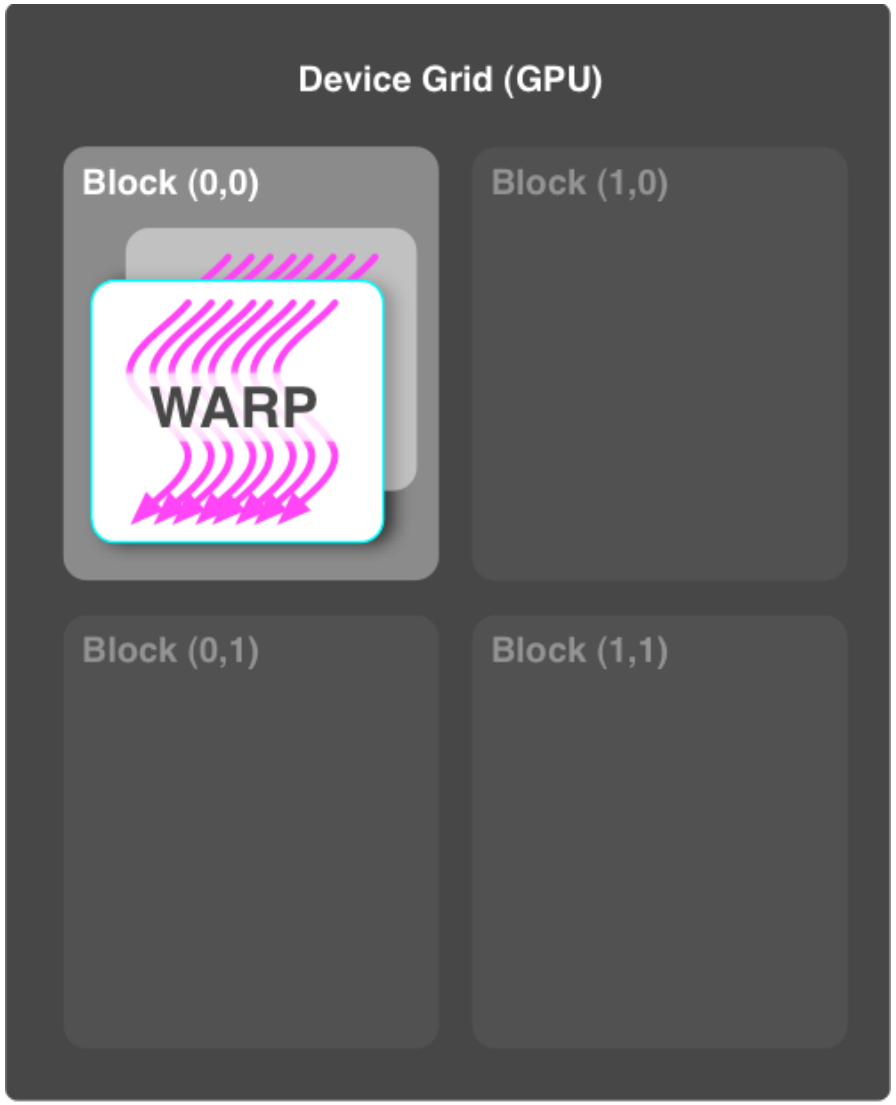
Ein CUDA Programm



CUDA Device Architektur



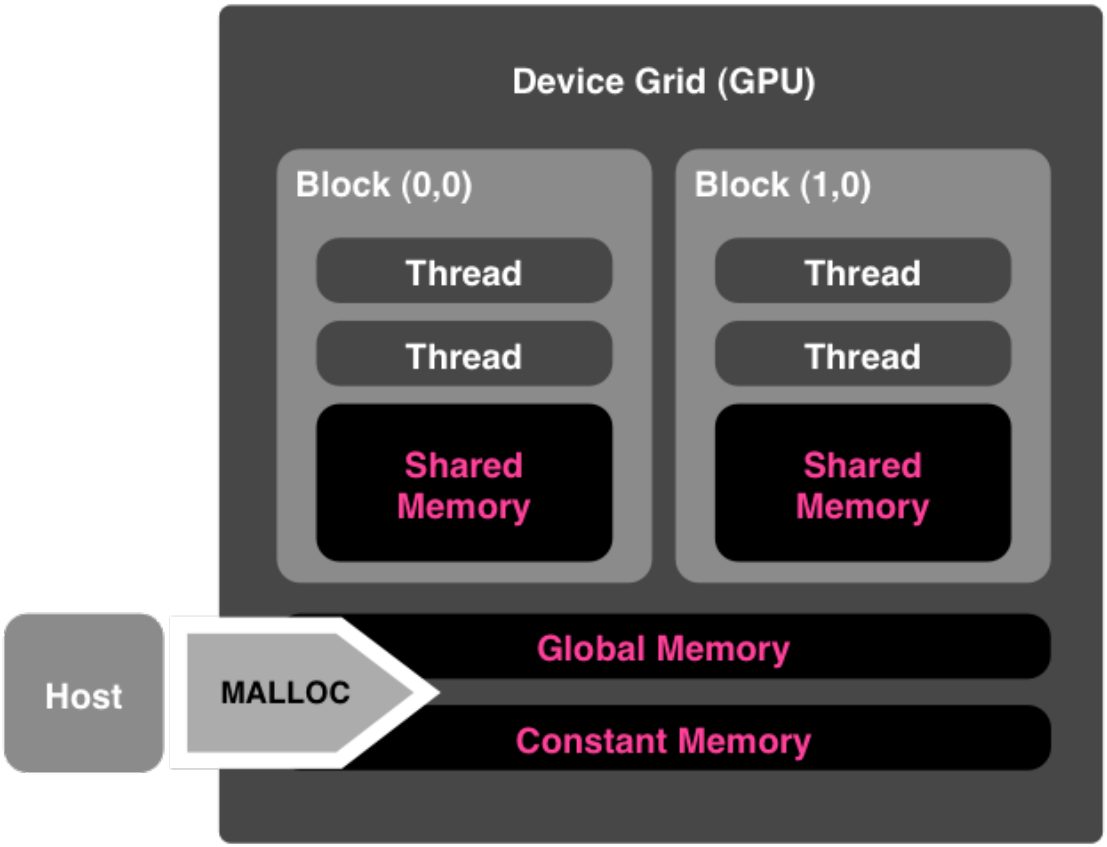
CUDA Device Architektur



CUDA Spracherweiterungen

Signatur	Aufruf durch	Ausführung auf	Anmerkungen
__host__	Host (CPU)	Host (CPU)	Standard
__global__	Host (CPU)	Device (GPU)	
__device__	Device (GPU)	Device (GPU)	

CUDA Memory Model



CUDA Memory Model (2)
Speicherallokierung

Signatur	Speicherort	Sichtbarkeit
__device__	Global Memory	Programmlaufzeit
__constant__	Constant Memory	Programmlaufzeit
__shared__	Shared Memory	Laufzeit des Blocks

Beispiel: Matrixprodukt

$$\underbrace{\begin{pmatrix} m_{11} & \cdots & m_{1n} \\ \vdots & \ddots & \vdots \\ m_{n1} & \cdots & m_{nn} \end{pmatrix}}_{M} \cdot \underbrace{\begin{pmatrix} n_{11} & \cdots & n_{1n} \\ \vdots & \ddots & \vdots \\ n_{n1} & \cdots & n_{nn} \end{pmatrix}}_{N} = \underbrace{\begin{pmatrix} p_{11} & \cdots & p_{1n} \\ \vdots & \ddots & \vdots \\ p_{n1} & \cdots & p_{nn} \end{pmatrix}}_{P}$$

Beispiel: Matrixprodukt

$$\underbrace{\begin{pmatrix} m_{11} & \cdots & m_{1n} \\ \vdots & \ddots & \vdots \\ m_{n1} & \cdots & m_{nn} \end{pmatrix}}_{M} \cdot \underbrace{\begin{pmatrix} n_{11} & \cdots & n_{1n} \\ \vdots & \ddots & \vdots \\ n_{n1} & \cdots & n_{nn} \end{pmatrix}}_{N} = \underbrace{\begin{pmatrix} p_{11} & \cdots & p_{1n} \\ \vdots & \ddots & \vdots \\ p_{n1} & \cdots & p_{nn} \end{pmatrix}}_{P}$$

Implementierung auf CPU

```
void mult_matrix(float *M, float *N, float *P)
{
  int i, j, k;
  for (i = 0; i < DIM; ++i) {
    for (j = 0; j < DIM; ++j) {
      float sum = 0;
      for (k = 0; k < DIM; ++k) {
        float a = M[i*DIM + k];
        float b = N[k*DIM + j];
        sum += a * b;
      }
      P[i*DIM + j] = sum;
    }
  }
}
```

Parallelisierung mit CUDA

```
void mult_matrix(float *M, float *N, float *P)
{


  /*
   * TODO:
   * - Allocate device memory
   * - Copy matrices to device
   * - Perform calculation
   * - Copy result and free matrices
   */



}
```

Parallelisierung mit CUDA

```
void mult_matrix(float *M, float *N, float *P)
{
  /* Allocate device memory */
  float *Md, *Nd, *Pd;
  size_t size = DIM*DIM * sizeof(float);
  cudaMalloc((void**) &Md, size);
  cudaMalloc((void**) &Nd, size);
  cudaMalloc((void**) &Pd, size);


  /* Copy matrices to device */
  /* Perform calculation */
  /* Copy result from device to host and free matrices */

}
```

Parallelisierung mit CUDA

```
void mult_matrix(float *M, float *N, float *P)
{
  /* Allocate device memory... */


  /* Copy matrices to device */
  cudaMemcpy(Md, M, size, cudaMemcpyHostToDevice);
  cudaMemcpy(Nd, N, size, cudaMemcpyHostToDevice);


  /* Perform calculation */
  /* Copy result from device to host and free matrices */


}
```

Parallelisierung mit CUDA

```
void mult_matrix(float *M, float *N, float *P)
{
  /* Allocate device memory... */
  /* Copy matrices to device... */

  /* Perform calculation */
  dim3 dimBlock(DIM, DIM);
  dim3 dimGrid(1,1);
  device_mult_matrix<<<dimGrid, dimBlock>>>(Md, Nd, Pd);



  /* Copy result from device to host and free matrices */

}
```

Parallelisierung mit CUDA

```
__global__ void device_mult_matrix(
  float *Md, float *Nd, float *Pd)
{
  /* Thread ID */
  int tx = threadIdx.x;
  int ty = threadIdx.y;

  /* Compute one value per thread */
  float v = 0;
  int k;
  for (k = 0; k < DIM; ++k) {
    float Md_value = Md[ty * DIM + k];
    float Nd_value = Nd[k * DIM + tx];
    v += Md_value * Nd_value;
  }

  /* Write to result matrix on device */
  Pd[ty * DIM + tx] = v;
}
```

Parallelisierung mit CUDA

```
void mult_matrix(float *M, float *N, float *P)
{
  /* Allocate device memory... */
  /* Copy matrices to device... */
  /* Perform calculation... */

  /* Copy result from device to host */
  cudaMemcpy(P, Pd, size, cudaMemcpyDeviceToHost);


  /*free matrices */
  cudaFree(Md);
  cudaFree(Nd);
  cudaFree(Pd);
}
```

CUDA Spracherweiterungen (2)

```
__syncthreads();
```

Benchmark Bitonic Sort