# CS4803DGC Design Game Consoles

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# Debug

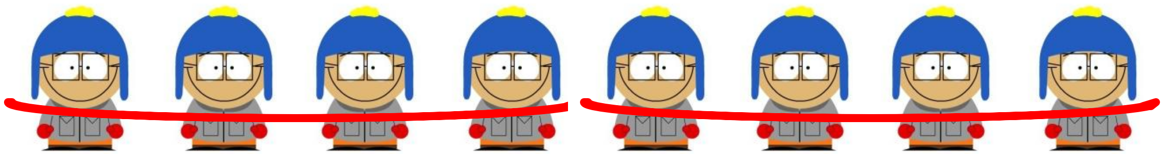
- Emulation mode
- Using CUDA-GDB
  - Not supported at States Lab ☹
  - All the GDB features are supported
  - Can set a break in kernel
  - Can make a progress only for a singe warp (a set of threads) {focused thread}
  - Classmate Anirudh's blog on CUDA-GDB
    - http://themethodofloci.blogspot.com/

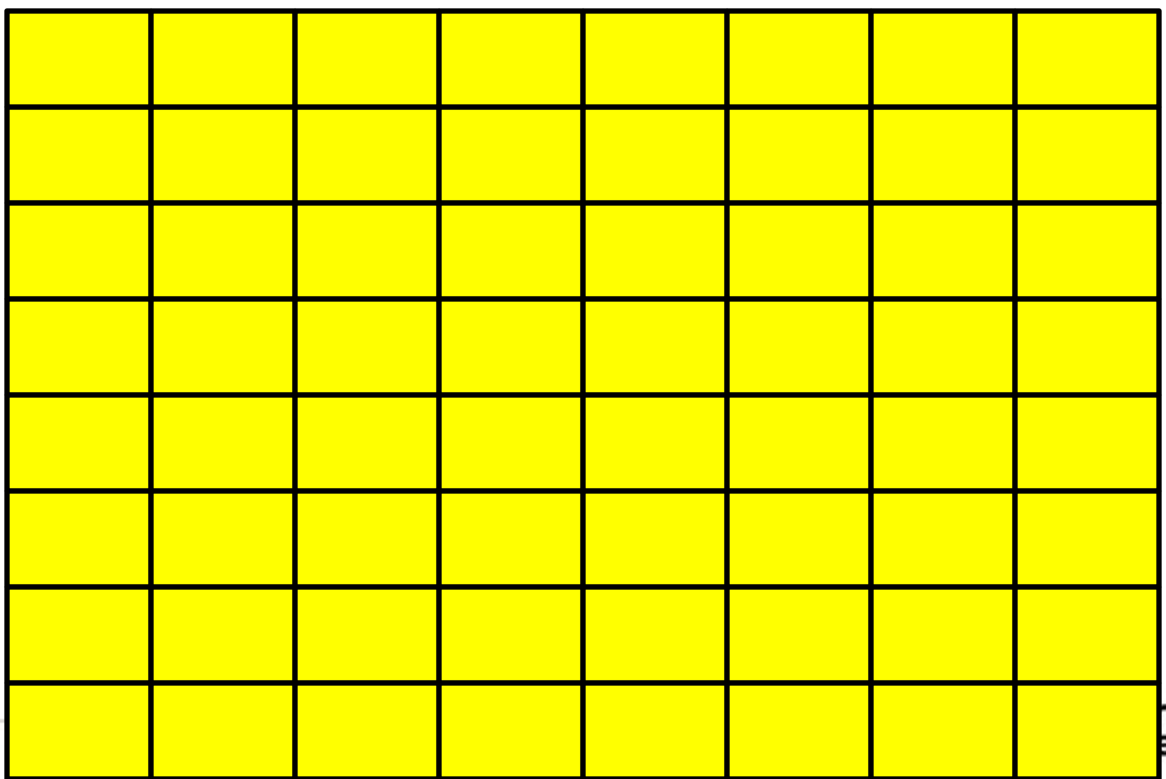
# Why MatrixMultiplication?

- Vector format is basic in graphics [xyzw]
- Matrix multiplication is a basic computation
- All the images are represented with matrix

# Matrix size = Multiple of block sizes

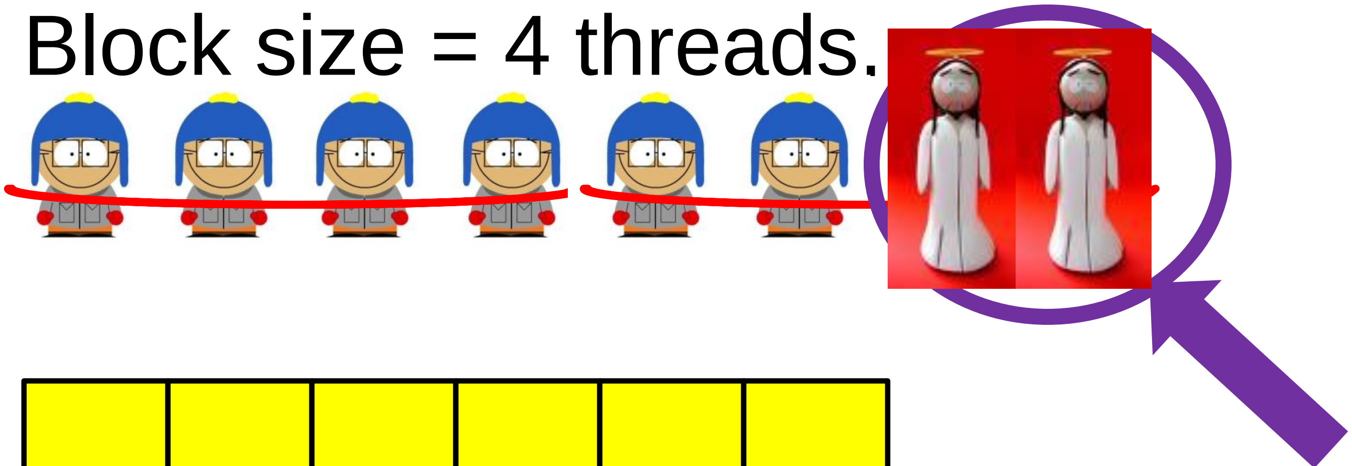
- Block size = 4 threads.

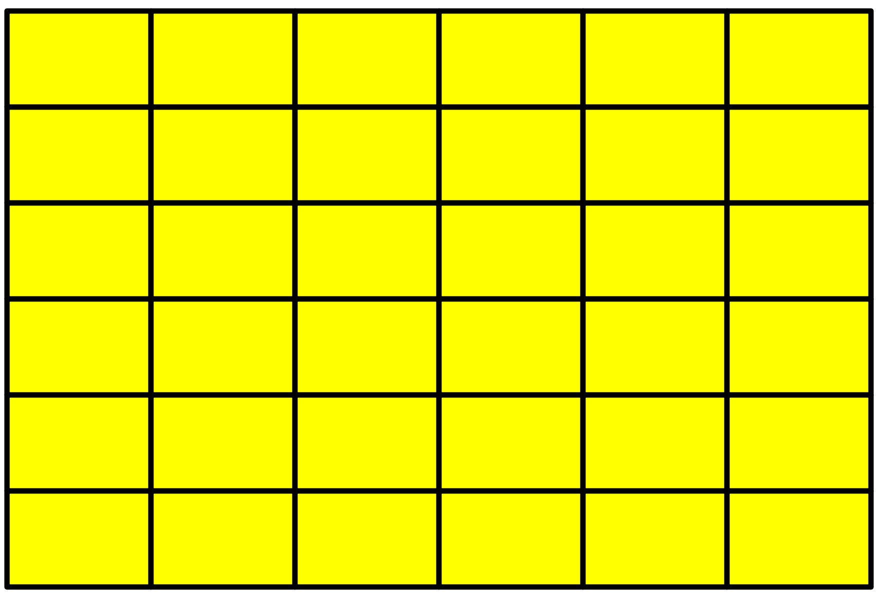




# Matrix size != Multiple of block sizes

- Block size = 4 threads.

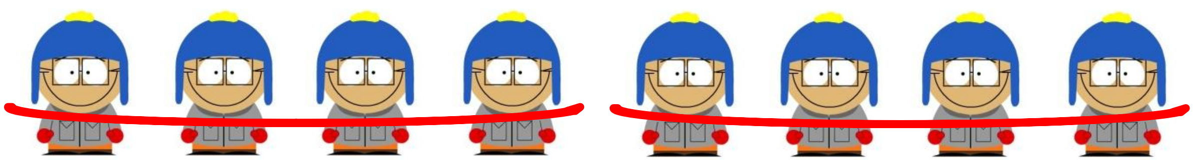




Shouldn't do any work
Why? It might bring a wrong data
And it might add the results into a wrong place
Segmentation faults!

# How? Use branch

- Use their names

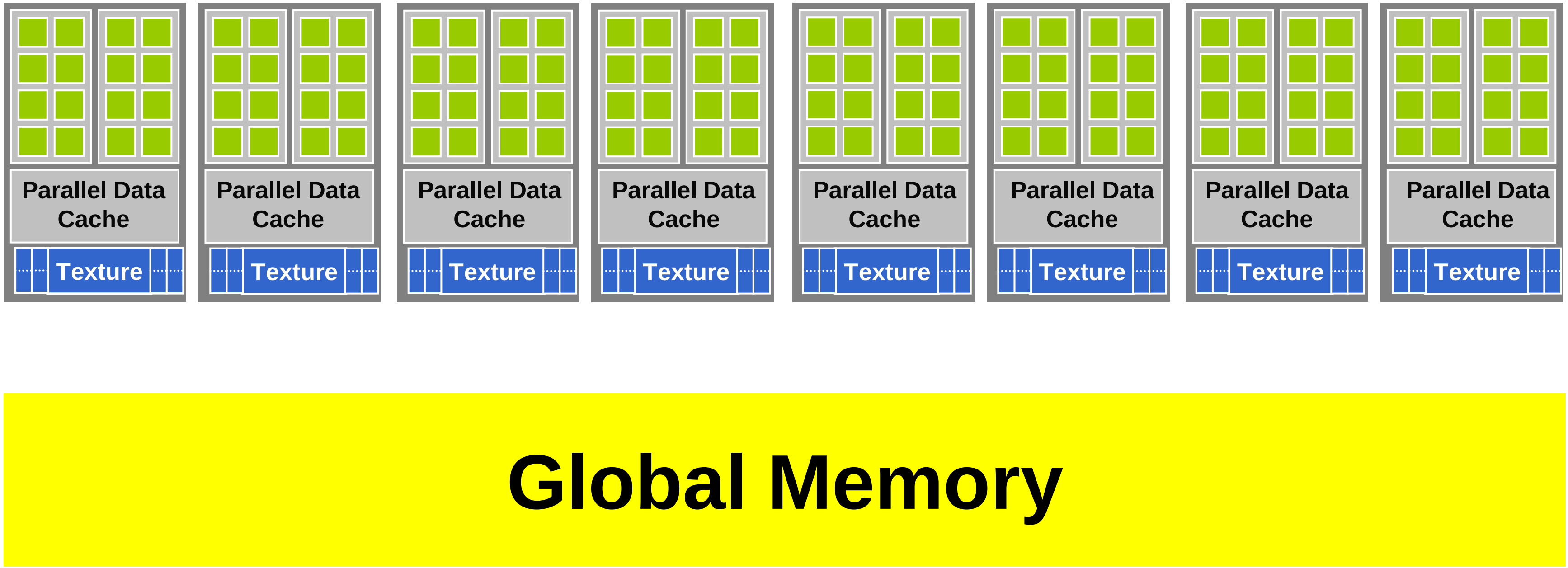


| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| blockIdx.x | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| threadIdx.x | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 |

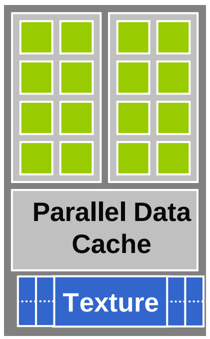
```
Indices  = BLOCK_SIZE & blockidx.x  + threadIdx.x
If(indices < M.width)  {
            // do work
}
```

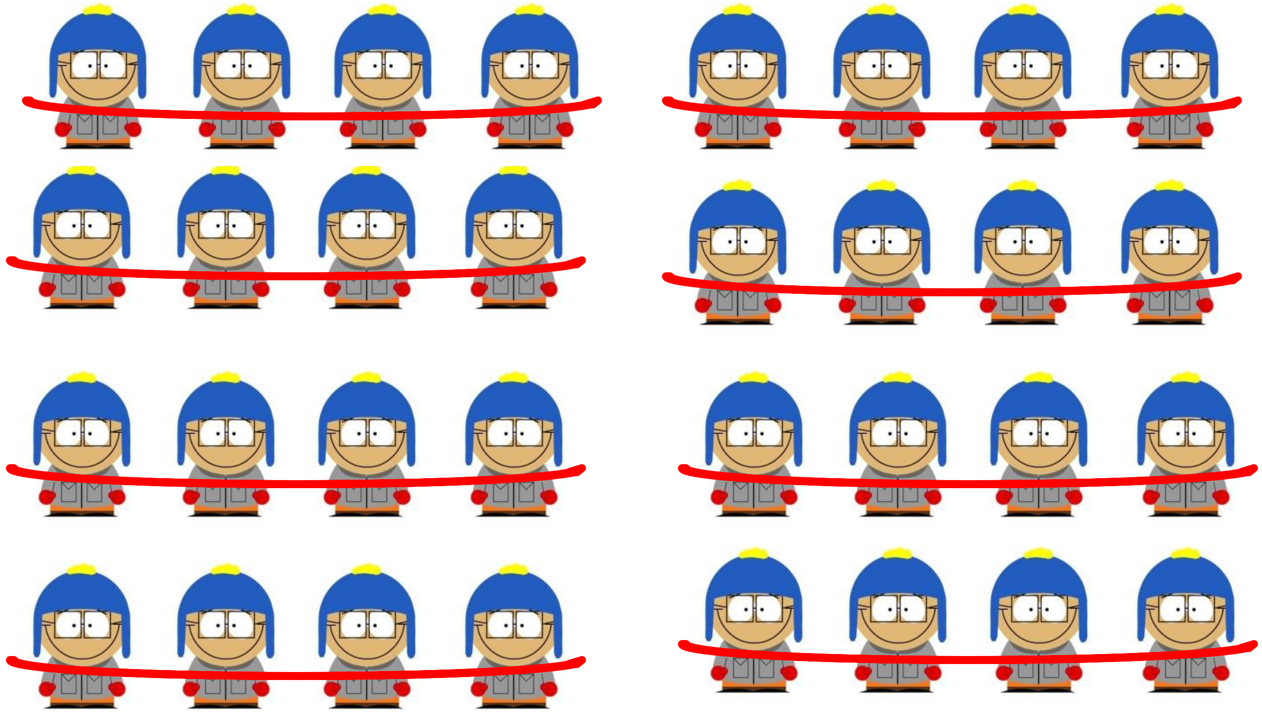
# Then why don't use BLOCK_SIZE=1?

- Resource allocation
- SIMD computation efficiency


Parallel Data Cache
Texture
Parallel Data Cache
Texture
Parallel Data Cache
Texture
Parallel Data Cache
Texture
Parallel Data Cache
Texture
Parallel Data Cache
Texture
Parallel Data Cache
Texture
Parallel Data Cache
Texture
Global Memory

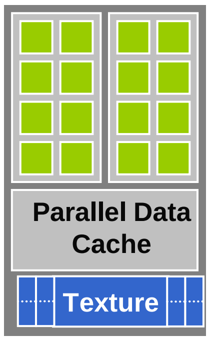
# Block size = 4

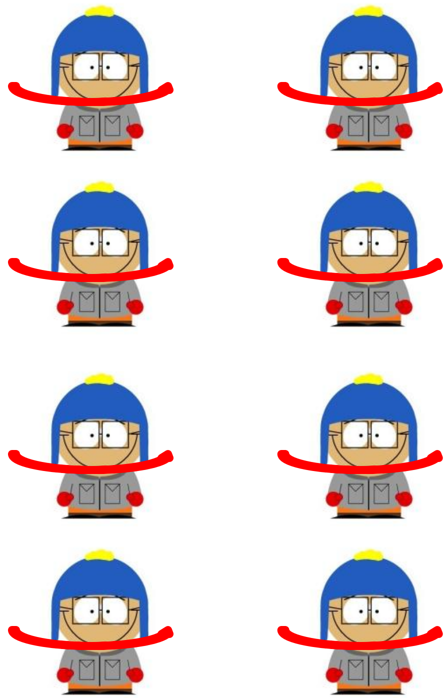


Total thread < 512 or total block < 8

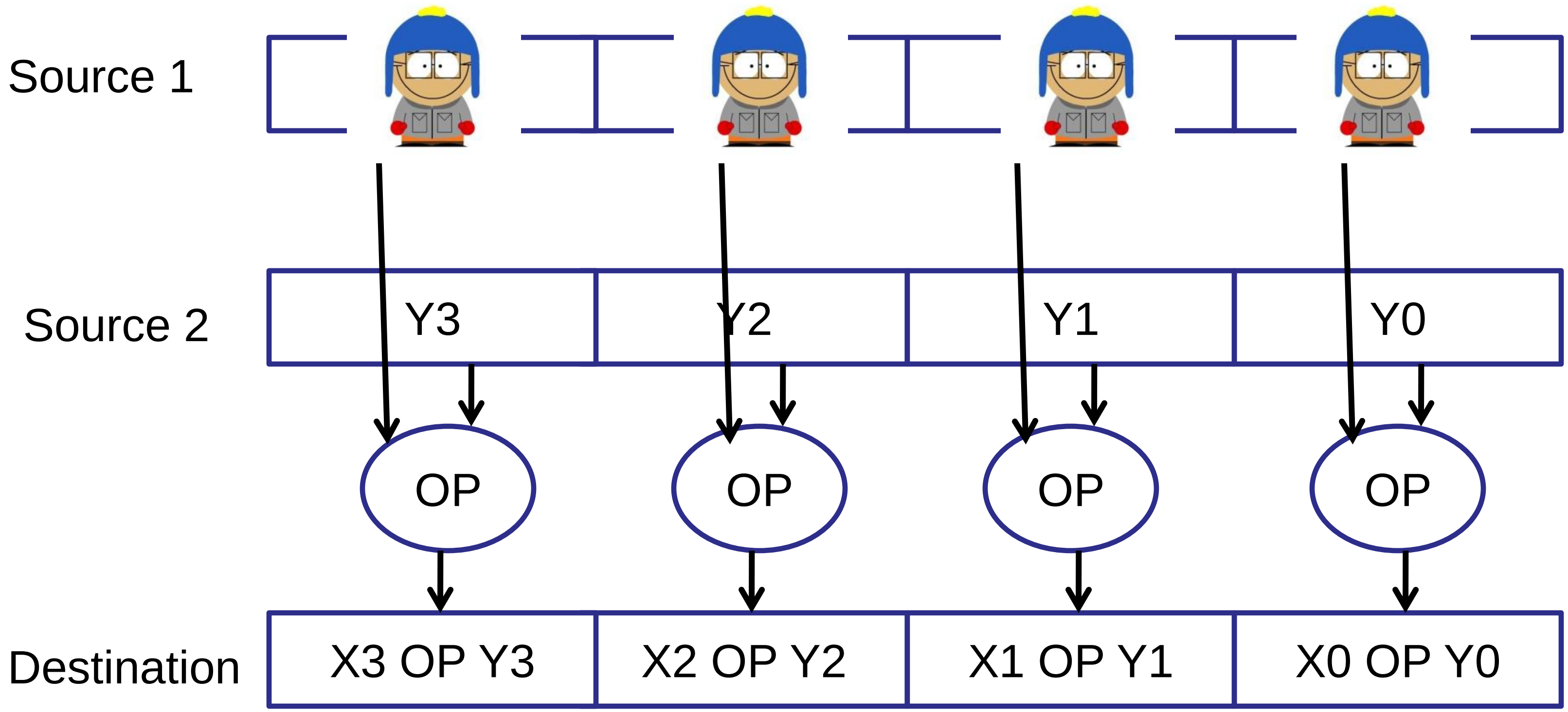
# Block size = 1



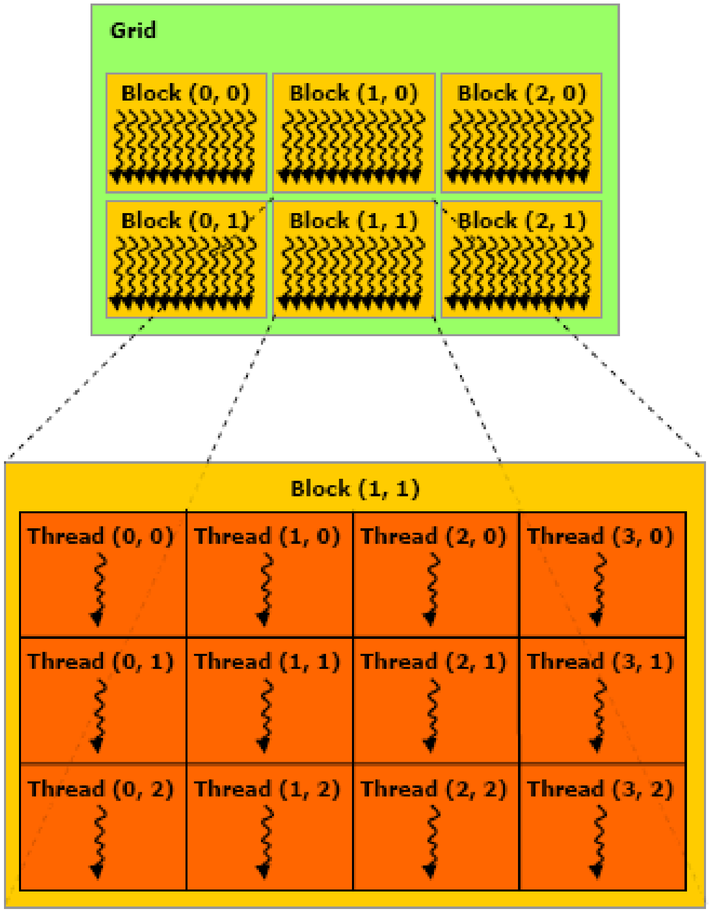
Total thread < 512 or total block < 8

# SIMD Execution Model




G80 architecture, SIMID unit size is 32,
So 32 threads is the best efficient block size

# Communication between blocks




- Shared memory cannot be accessible by other blocks

# Convolution

- Used by many applications for engineering and mathematics.
- Blur filters or edge detection.

Original Image

Blur convolution filter applied to the source image

# Math

- Mathematically, a convolution measures the amount of overlap between two functions.

$$r(i) = (s * k)(i) = \int s(i-n)k(n)dn$$

- Discrete terms

$$r(i) = (s * k)(i) = \sum_n s(i-n)k(n).$$

- Separable convolution (CUDA SDK)

$$r(i) = (s * k)(i, j) = \sum_n \sum_m s(i-n, j-m)k(n, m)$$

# Convolution?

Input

| | | | | |
|---|---|---|---|---|
| 23 | 12 | 25 | 36 | 10 |
| 73 | 26 | 99 | 56 | 2 |
| 65 | 11 | 5 | 26 | 76 |
| 83 | 67 | 52 | 32 | 17 |
| 34 | 84 | 46 | 99 | 32 |

Kernel

| | | |
|---|---|---|
| 1 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 1 |

# Convolution

| | | | | |
|---|---|---|---|---|
| 23 | 12 | 25 | 36 | 10 |
| 73 | 26 | 99 | 56 | 2 |
| 65 | 11 | 5 | 26 | 76 |
| 83 | 67 | 52 | 32 | 17 |
| 34 | 84 | 46 | 99 | 32 |

| | | |
|---|---|---|
| 26 | 99 | 56 |
| 11 | 5 | 26 |
| 67 | 52 | 32 |

*

| | | |
|---|---|---|
| 1 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 1 |

(26 * 1) +
(99 * 0) +
(56 * 1) +
(11 * 0) +
(5 * 1) +
(26 * 0)+
(67 * 1) +
(52 * 0) +
(32 * 1)

⟹

| | | | | |
|---|---|---|---|---|
| 23 | 12 | 25 | 36 | 10 |
| 73 | 26 | 99 | 56 | 2 |
| 65 | 11 | 18 | 26 | 76 |
| 83 | 67 | 52 | 32 | 17 |
| 34 | 84 | 46 | 99 | 32 |

# Boundary

| | | | | |
|---|---|---|---|---|
| 23 | 12 | 25 | 36 | 10 |
| 73 | 26 | 99 | 56 | 2 |
| 65 | 11 | 5 | 26 | 76 |
| 83 | 67 | 52 | 32 | 17 |
| 34 | 84 | 46 | 99 | 32 |

| | | |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 23 | 12 |
| 0 | 73 | 26 |

*

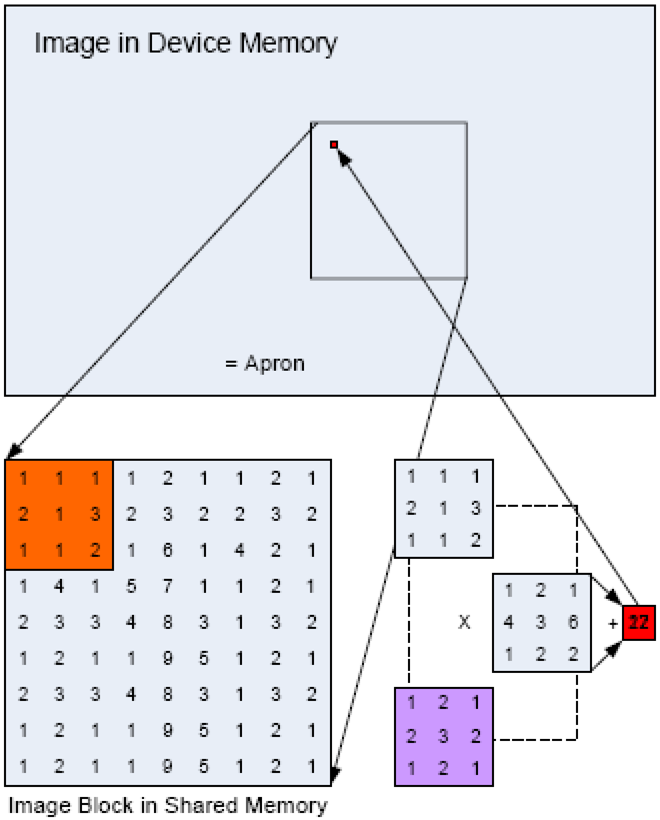
| | | |
|---|---|---|
| 1 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 1 |

(0 * 1) +
(0 * 0) +
(0 * 1) +
(0 * 0) +
(23 * 1) +
(12 * 0)+
(0 * 1) +
(73 * 0) +
(26 * 1)

⟹

| | | | | |
|---|---|---|---|---|
| 23 | 12 | 25 | 36 | 10 |
| 73 | 26 | 99 | 56 | 2 |
| 65 | 11 | 49 | 26 | 76 |
| 83 | 67 | 52 | 32 | 17 |
| 34 | 84 | 46 | 99 | 32 |

# A Naïve Implementation




A naïve convolution algorithm. A block of pixels from the image is loaded into an array in shared memory. To process and compute an output pixel (red), a region of the input image (orange) is multiplied element-wise with the filter kernel (purple) and then the results are summed. The resulting output pixel is then written back into the image.

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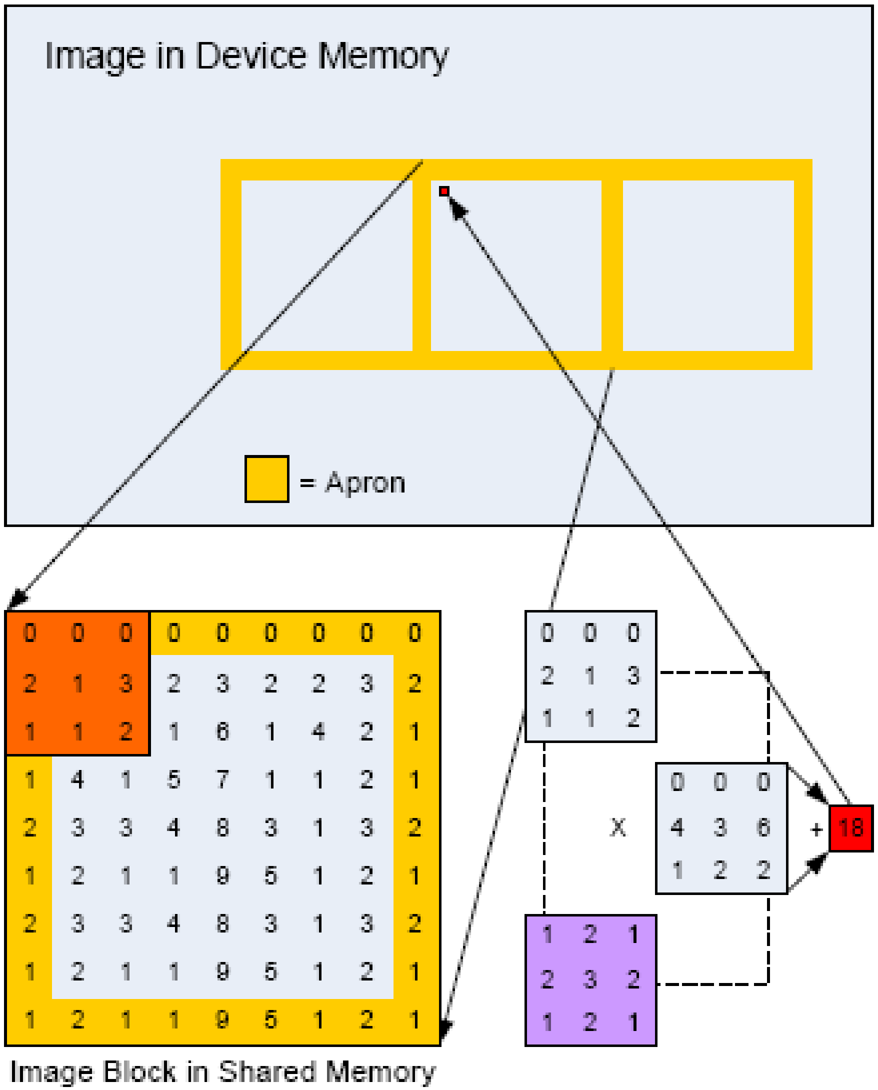
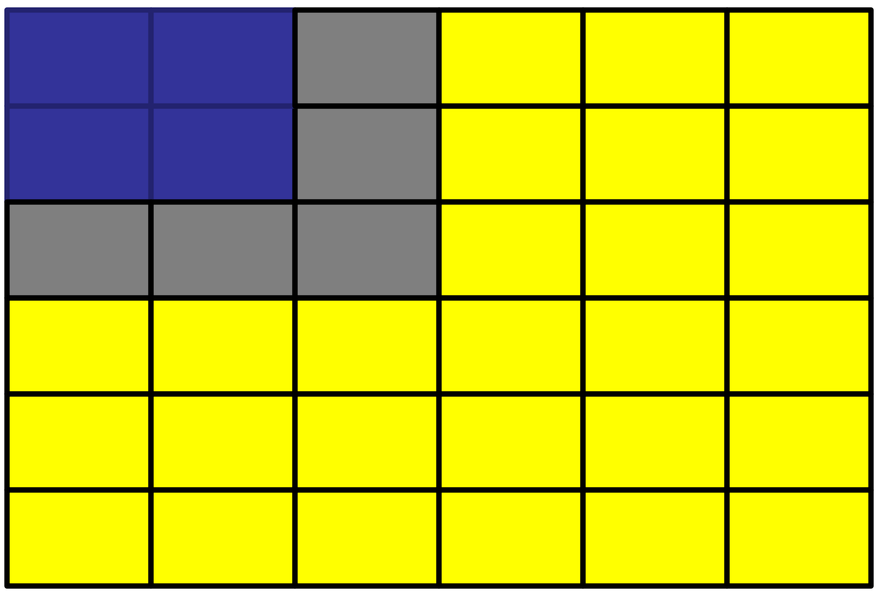
# Naïve Implementation: Shared Memory and the Apron

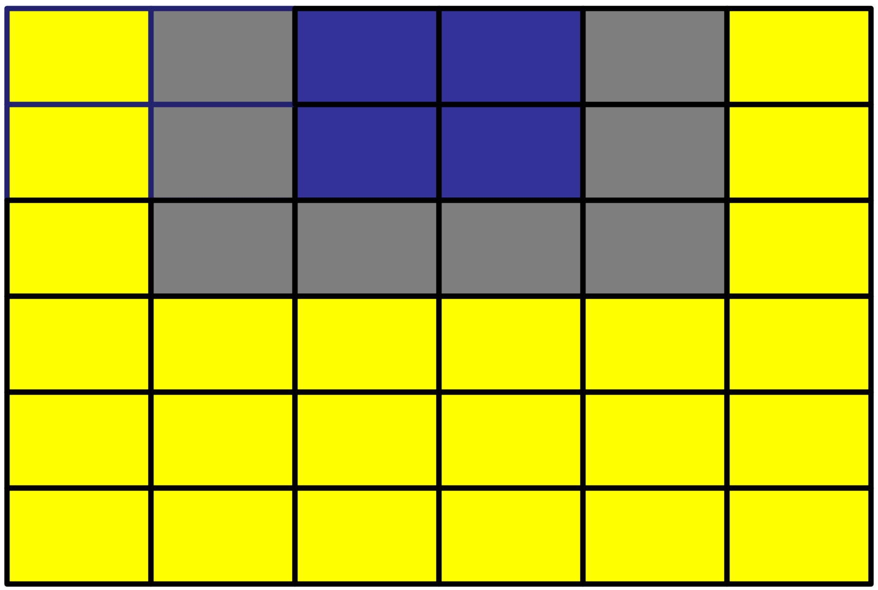



Each thread block must load into shared memory the pixels to be filtered and the apron pixels.

# Apron



# Apron



# Apron