Università degli Studi di Firenze

Corso di Laurea Magistrale in Ingegneria Informatica

Progetto finale del corso di Parallel Computing:

Kernel Image Processing

Studente: Kevin Maggi

Anno Accademico 2021/2022

Overview

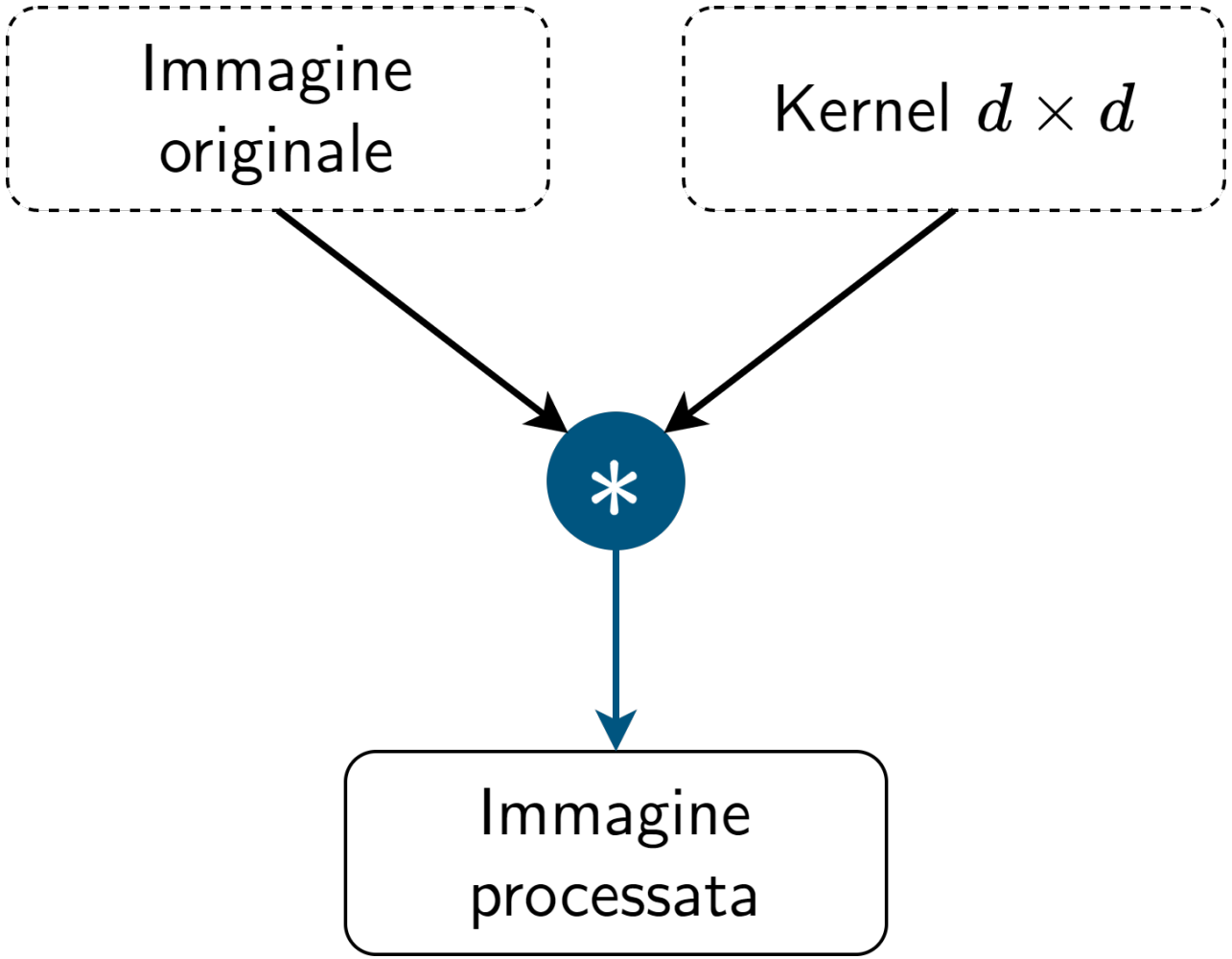
Contesto: Kernel Image Processing

Implementazioni: C sequenziale
C + OpenMP
CUDA-C

Obiettivo: Speed up

Kernel Image Processing

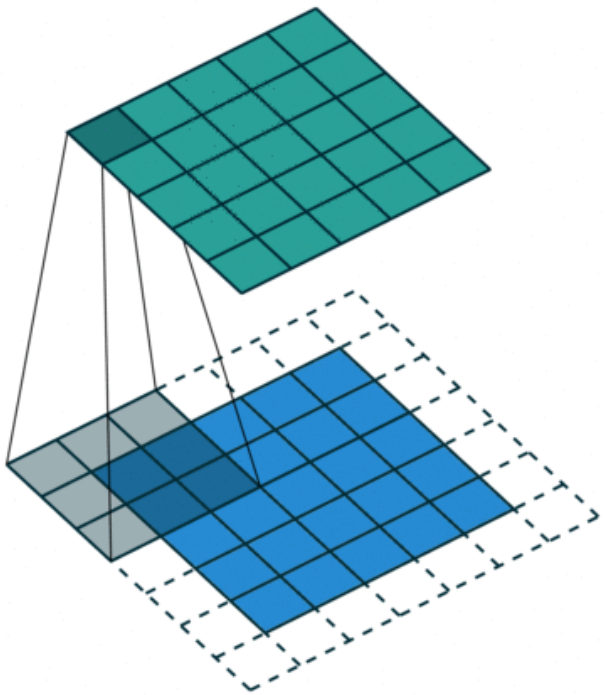
Principio



Kernel Image Processing

Convoluzione

$$P_{x,y} = \sum_{dx=-d}^{d} \sum_{dy=-d}^{d} K_{dx,dy} I_{x+dx,y+dy}$$



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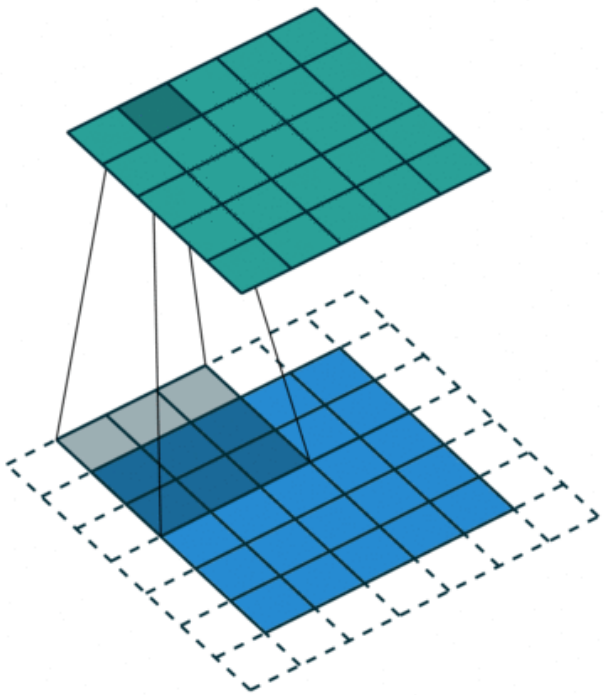

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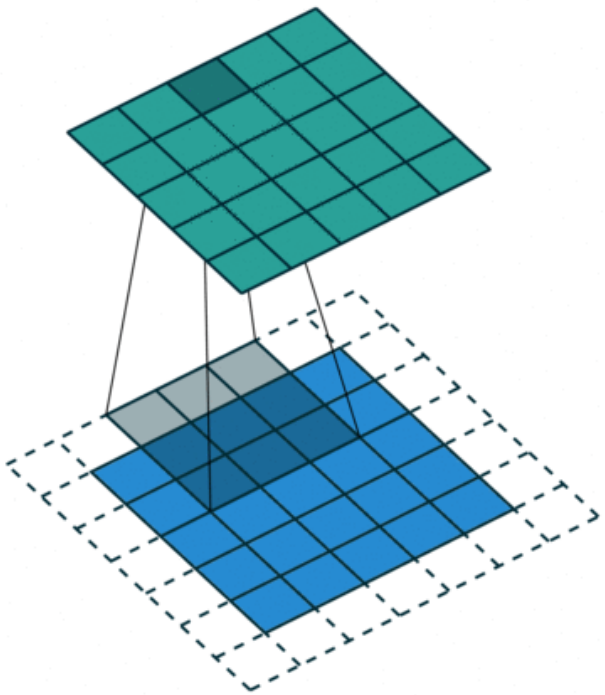

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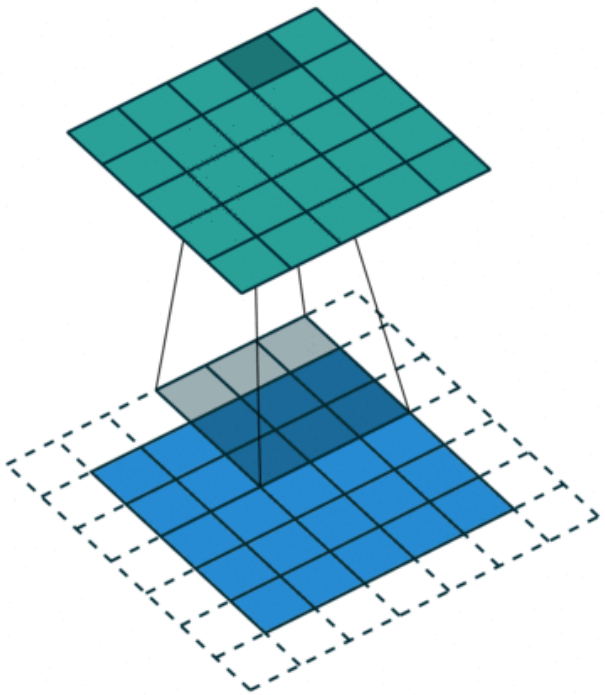

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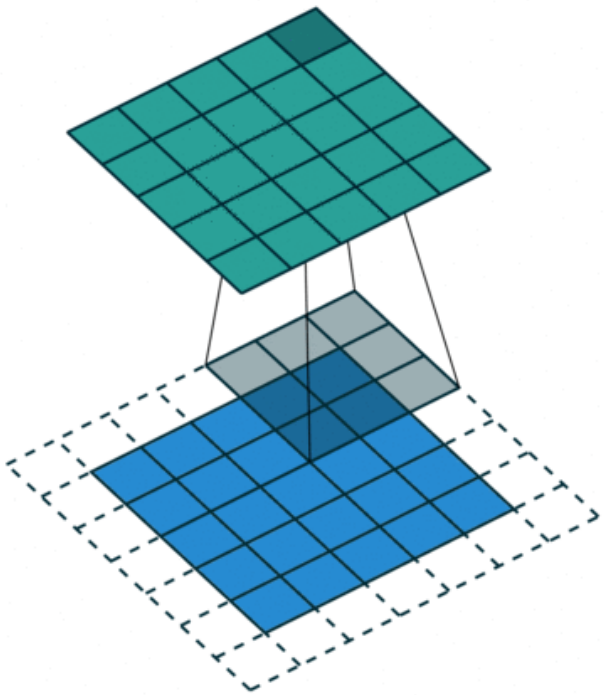

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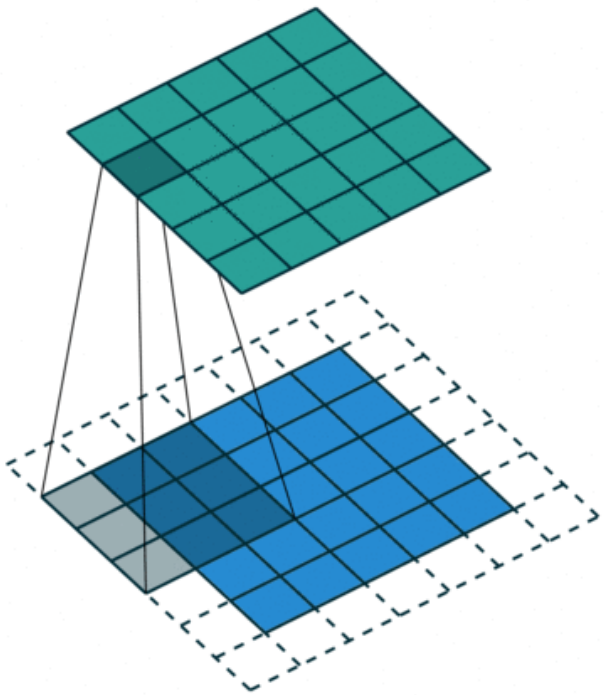

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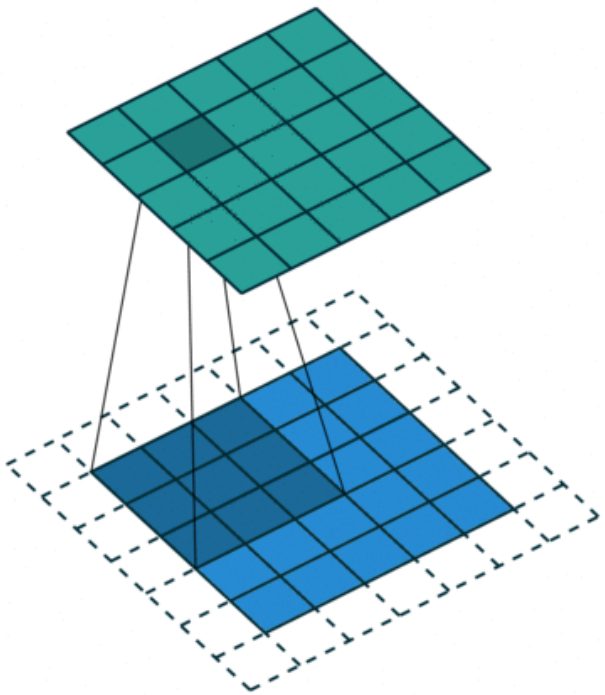

Kernel Image Processing

Edge Handling

Gestione degli elementi del bordo (di spessore $\frac{d-1}{2}$):

- Kernel crop
- Crop
- Mirror
- Wrap
- Extend

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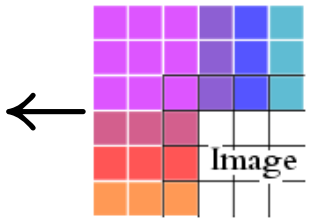


Blur

Blur

Box blur

$$\downarrow$$

$$K = \frac{1}{d^2} \overbrace{\begin{pmatrix} 1 & \cdots & 1 \\ \vdots & \ddots & \vdots \\ 1 & \cdots & 1 \end{pmatrix}}^{\mathrm{d}}$$

Gaussian blur

$$\downarrow$$

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

$$\wr$$

$$K = \frac{1}{2^{2(d-1)}} \omega\omega^T$$

con ω d-esima riga del triangolo di Tartaglia

Pseudocodice

```
for y from 1 to height
  for x from 1 to width
    for c in channels
      sum = 0;
        for i from 1 to d
          for j from 1 to d

            // edge handling

            sum += I(x,y,c)*K(i,j);
      sum = sum/K.weight;
      P(x,y,c) = sum;
```

Profiling

Unico hotspot

↓

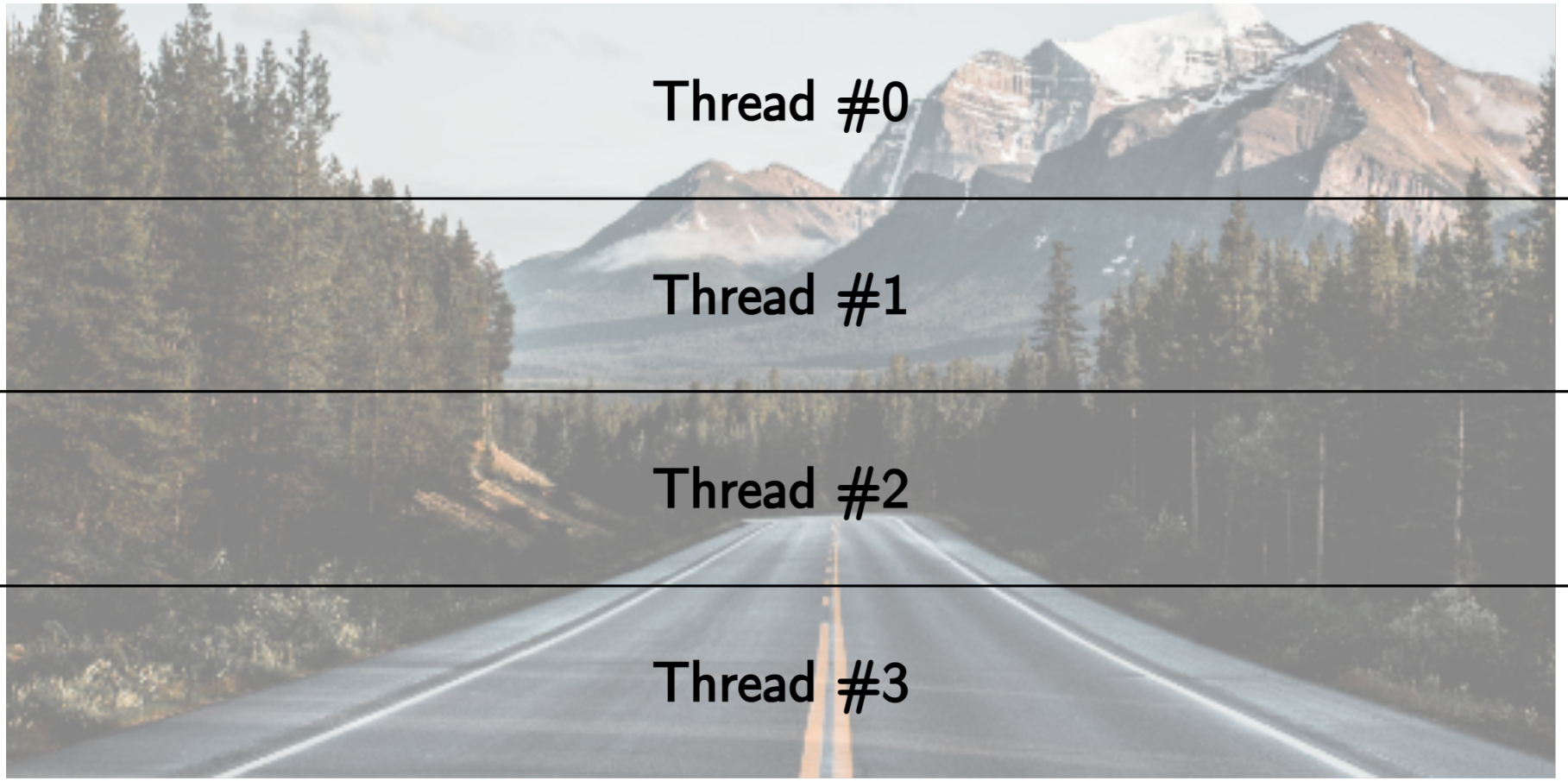
100% del tempo di computazione

OpenMP

Stesso codice → una singola direttiva per il ciclo più esterno

```
#pragma omp parallel for
    default(none)
    shared(I, K, P)
    private(sum, indexes)
    firstprivate(radius)

    schedule(static)
    num_threads(4)
```

Decompisizione dei dati



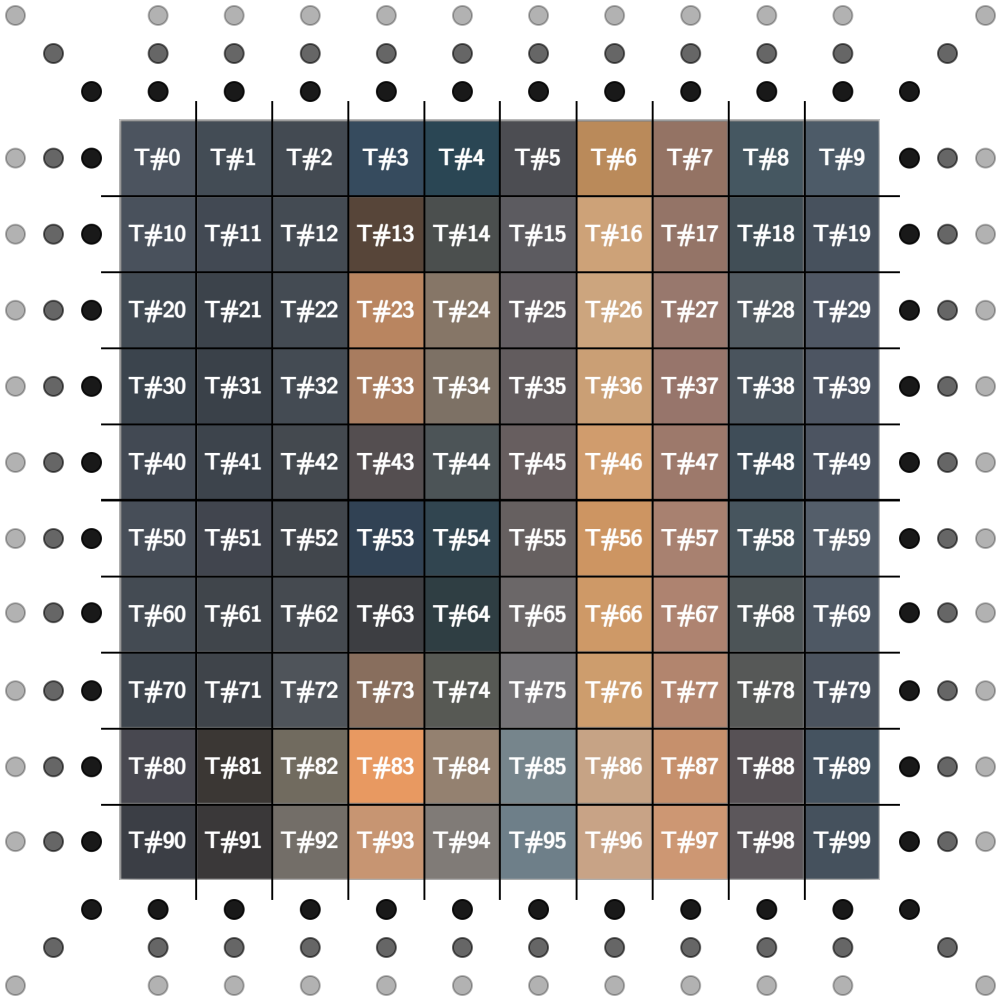
OpenMP

Alternative

```
#pragma parallel
for y from 1 to height
  for x from 1 to width
    for c in channels
      sum = 0;
        #pragma for reduction(+:sum)
        for i from 1 to d
          for j from 1 to d
            sum += I(x,y,c)*K(i,j);
```

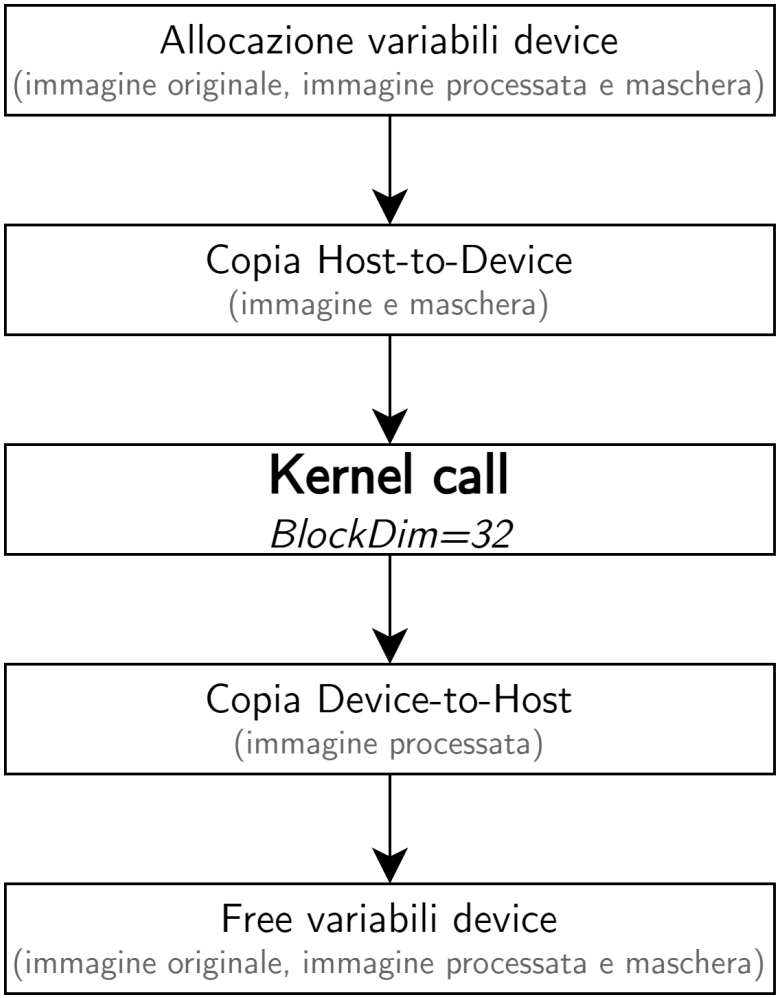
⇒ performance peggiori

Decomposizione dei dati



1^o step

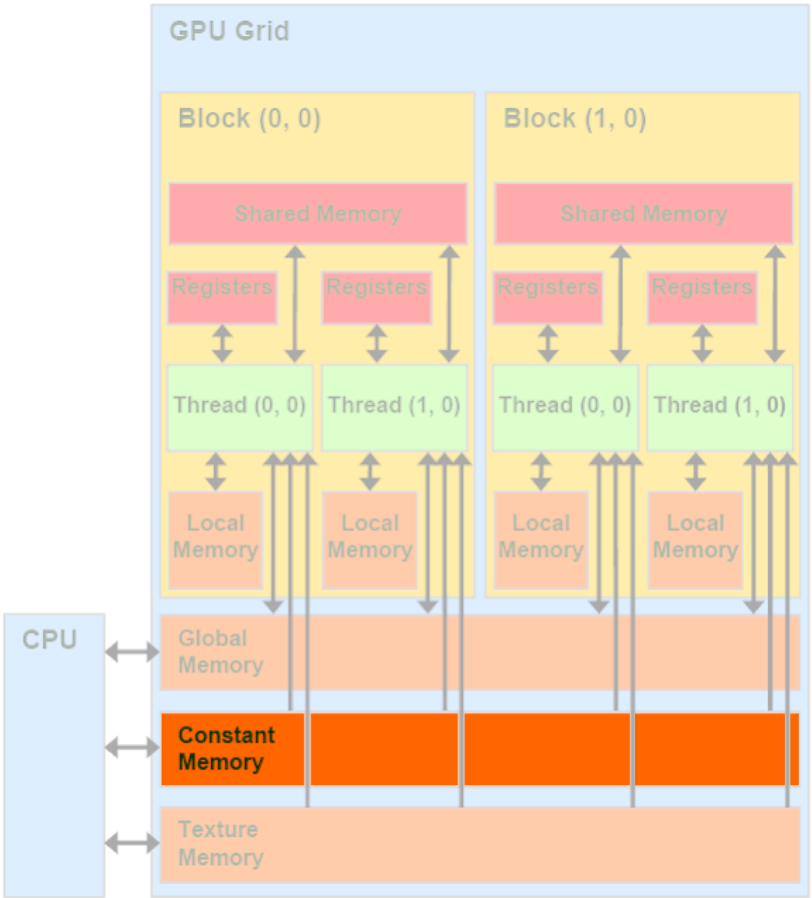
Versione naïve




```
x = fx(blockIdx.x, threadIdx.x);
y = fy(blockIdx.y, threadIdx.y);

for c in channels
  sum = 0;
    for i from 1 to d
      for j from 1 to d

        // edge handling

        sum += I(x,y,c)*K(i,j);
  sum = sum/K.weight;
  P(x,y,c) = sum;
```

2^o step

Constant memory



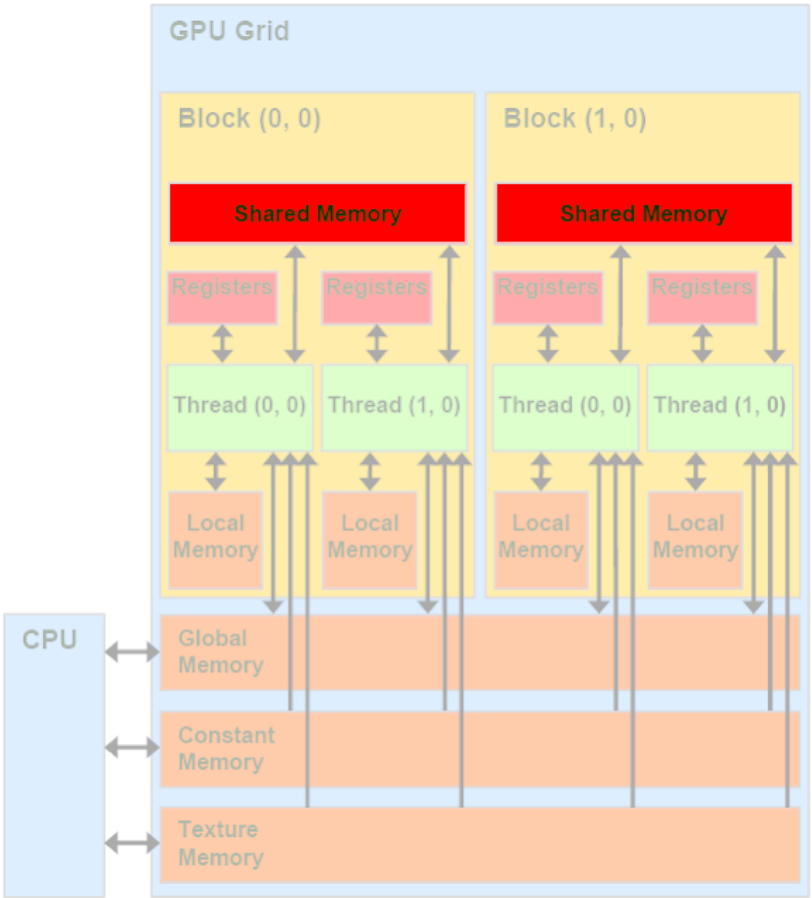
Allocazione statica

↓

```
__constant__ KERNEL[25*25]
```

3° step

Shared memory



Kernel call

BlockDim=16

```
x = fx(blockIdx.x, threadIdx.x);
y = fy(blockIdx.y, threadIdx.y);

// multibatch loading
// with edge handling

for c in channels
  sum = 0;
    for i from 1 to d
      for j from 1 to d
        sum += I(x,y,c)*K(i,j);
  sum = sum/K.weight;
  P(x,y,c) = sum;
```

4^o step

Pinned memory

$$8000 \times 6000 \text{ px} \rightarrow \sim 150\text{MB di memoria}$$

$$\downarrow$$

con poca memoria può essere fatto swap su disco

$$\downarrow$$

immagine e maschera allocate con **pinned memory**

Test

Macchina:

- GPU: NVIDIA GeForce 940MX: Compute Capability 5.0, 512 CUDA core, Maxwell Architecture
- CPU: Intel Core i7-6500U con **Hyperthreading**: 2.5GHz up to 3.1GHz, 2 core/4 thread
- RAM: 8GB

Input:

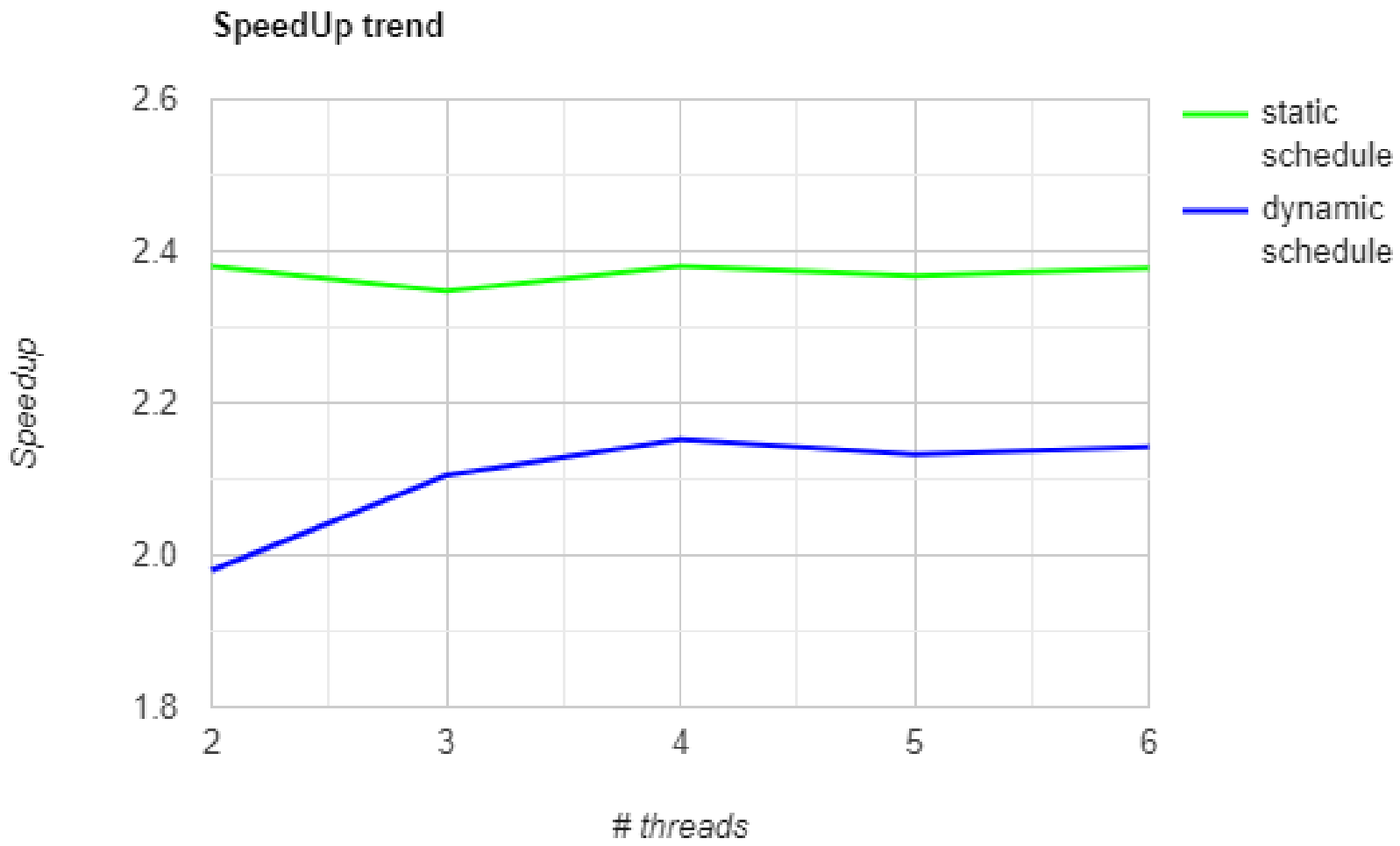
- immagini: 5K, 6K, 7K, 8K
- d: 7, 13, 19, 25

Risultati

OpenMP: scheduling statico, 4 thread

Input		speed up
5K	$d = 7$	2.28
	$d = 13$	2.32
	$d = 19$	**2.55**
	$d = 25$	2.38
6K	$d = 7$	2.28
	$d = 13$	2.31
	$d = 19$	**2.55**
	$d = 25$	2.38
7K	$d = 7$	2.27
	$d = 13$	2.32
	$d = 19$	**2.55**
	$d = 25$	2.39
8K	$d = 7$	2.19
	$d = 13$	2.12
Media		**2.36**

thread ottimale e scheduling migliore

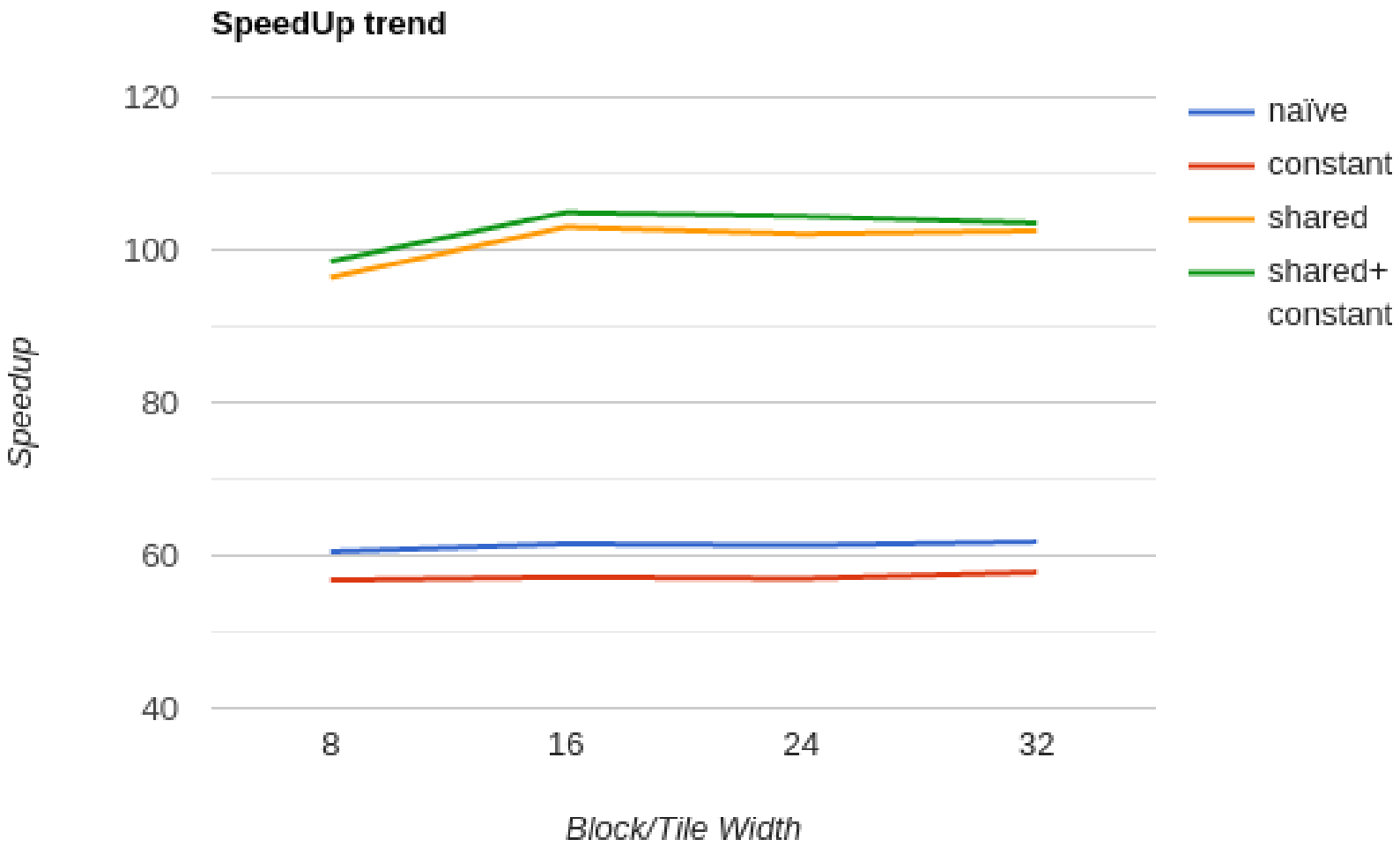


Risultati

CUDA: block width 32 / 16 (shared)

Input		speed up			
		naïve	constant	shared	constant+shared
5K	$d = 7$	40.7	40.7	45.6	49.6
	$d = 13$	52.7	49.9	73.8	78.5
	$d = 19$	60.5	57.6	97.4	100.8
	$d = 25$	61.1	57.7	101.7	105.5
6K	$d = 7$	41.4	40.4	47.7	52.0
	$d = 13$	52.6	49.9	73.6	78.5
	$d = 19$	60.9	58.1	98.0	101.0
	$d = 25$	61.8	57.8	102.5	105.3
7K	$d = 7$	42.2	41.6	48.4	52.2
	$d = 13$	52.9	50.8	73.8	79.2
	$d = 19$	61.1	58.2	97.7	101.2
	$d = 25$	62.0	57.9	102.9	106.2
8K	$d = 7$	40.8	40.3	46.8	50.9
	$d = 13$	48.5	46.4	68.1	72.6
Media		**53.0**	**50.6**	**77.4**	**81.4**

Block width ottimale



Pinned memory profiling

Performance non migliori

↓

↑ throughput (da 1.56 GB/s a 1.59 GB/s)

↓

Istanziazione più lenta

Grazie per l'attenzione