UNIVERSITÀ DEGLI STUDI DI PADOVA

Spatial filtering

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Agenda

- Intro to local operations
- Correlation and convolution
- Local filters overview

Spatial operations

- Many different ways of transforming an image
- Single-pixel operations
  - Intensity transform, histogram equalization, …
  - The output value of each pixel depends on th [illegible] value

Last modules

- Local operations
  - Linear and non-linear filters
  - The output value depends on the initial values of the pixel + its neighbors
- Geometric transforms
  - Scaling, rotation, …
  - "Moving" points

Spatial operations

- Many different ways of transforming an image
- Single-pixel operations
  - Intensity transform, histogram equalization, …
  - The output value of each pixel depends on the pixel initial value
- Local operations
  - Linear and non-linear filters
  - The output value depends on the initial values of the pixel + its neighbors
- Geometric transforms
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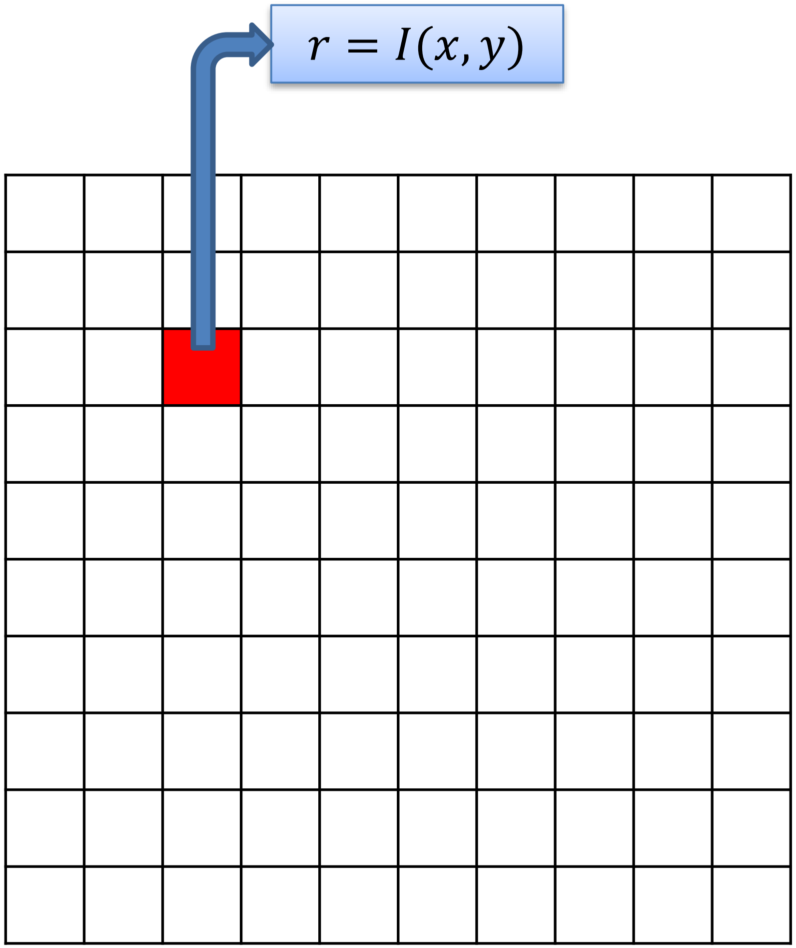
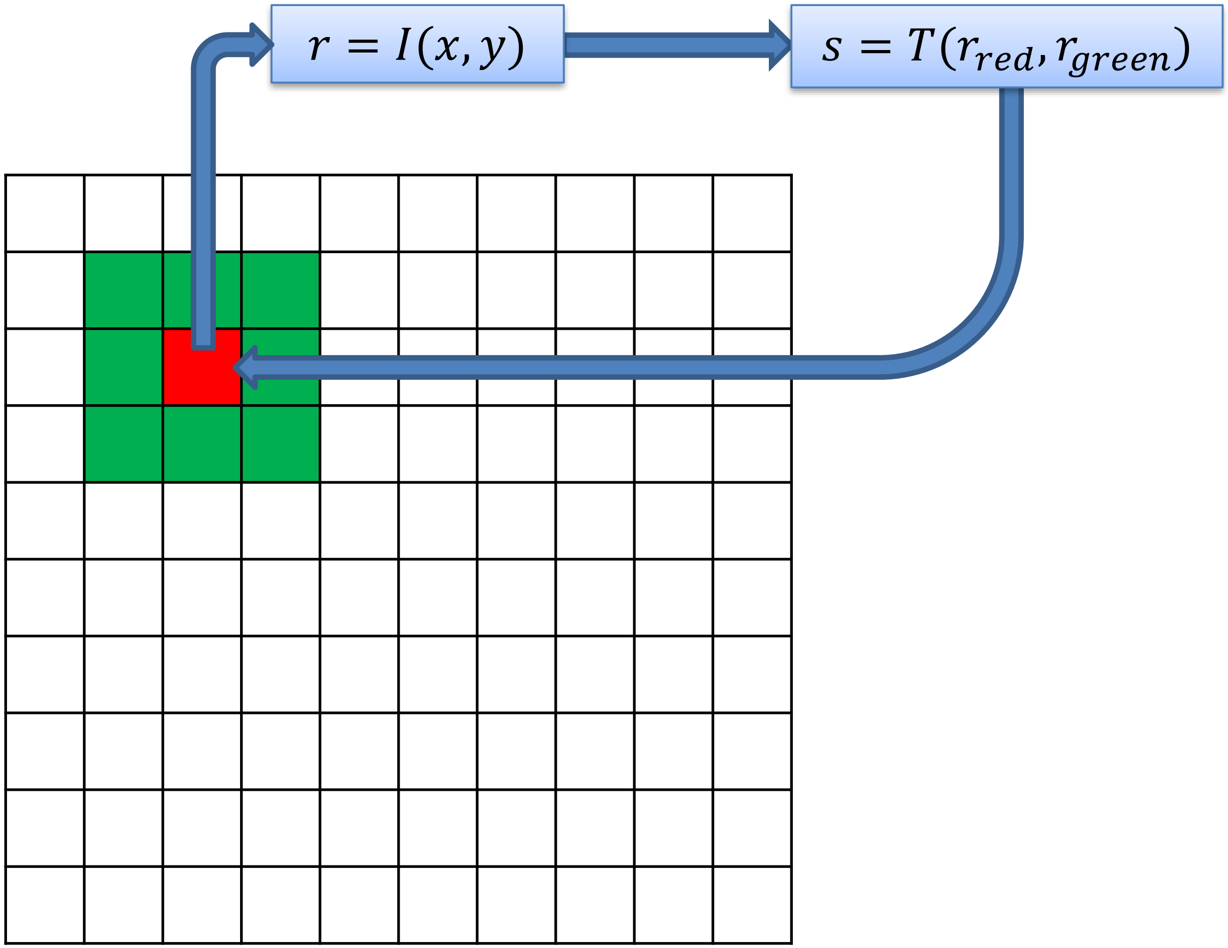
Local operations

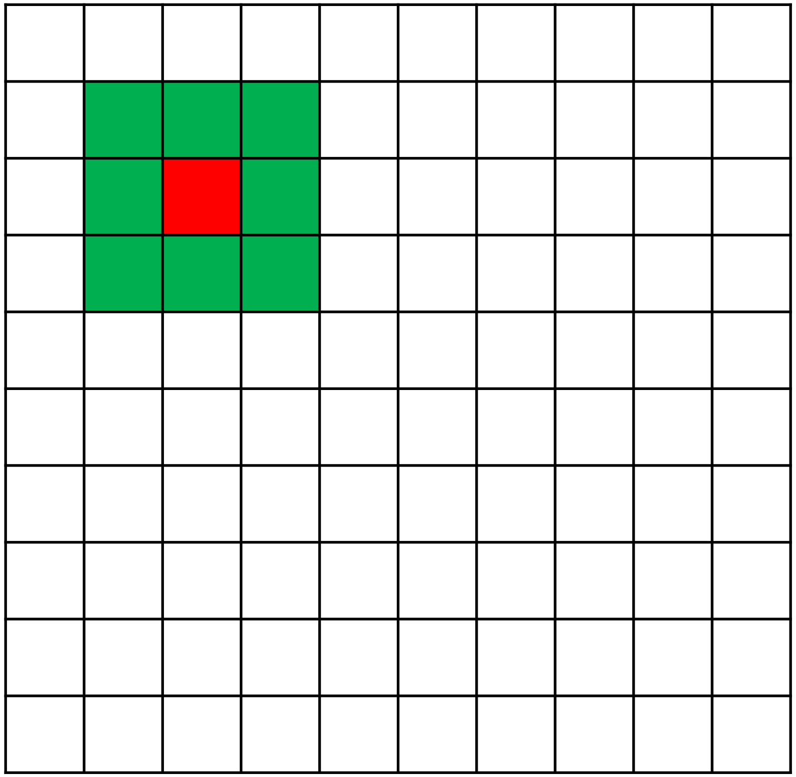


Local operations



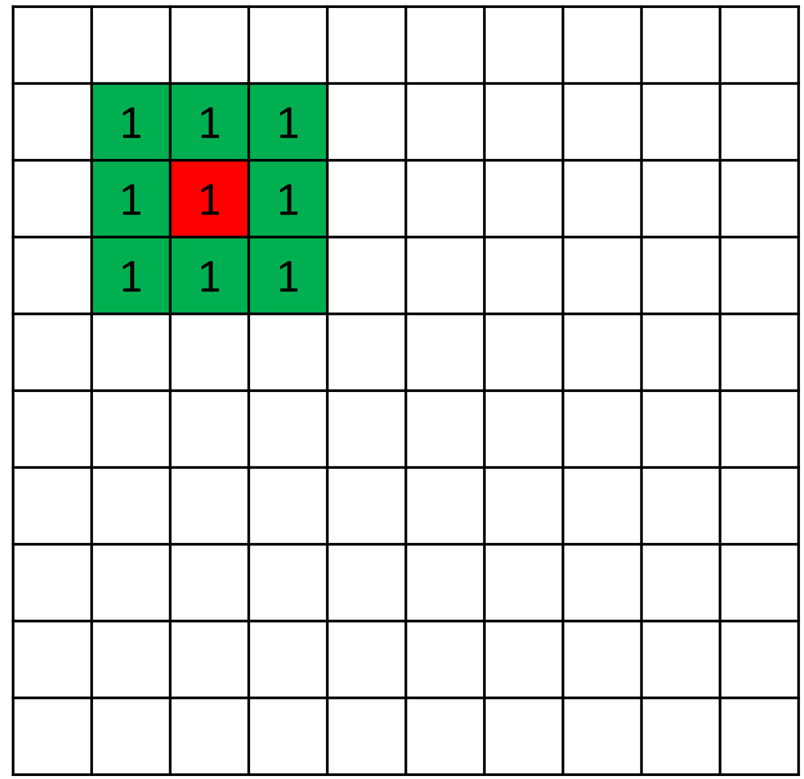
Local operations

- Local operations are defined based on a **filter/kernel**
- The kernel defines
  - A neighborhood (the set of "green" pixels)



Local operations

- Local operations are defined based on a **filter/kernel**
- The kernel defines
  - A neighborhood (the set of "green" pixels)
  - A weight associated with each pixel involved in the computation



Spatial filters

- Local operations are performed in the **spatial domain** of the image (the space containing the pixels)
  – AKA spatial filtering
  – The kernel is AKA spatial filter

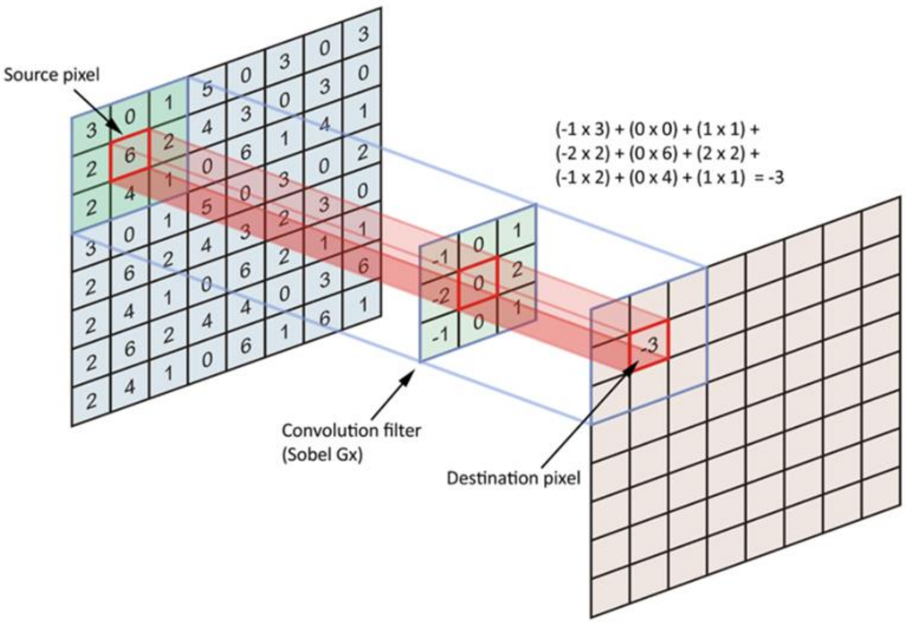
Convolution

- How is the spatial filter applied to the image?
- Several options are available
  - Evaluating a correlation/convolution
  - Calculating the min/max
  - …
- Depending on the processing applied to the image the filter can be linear or non-linear

Linear filtering
Non-linear filtering

Correlation

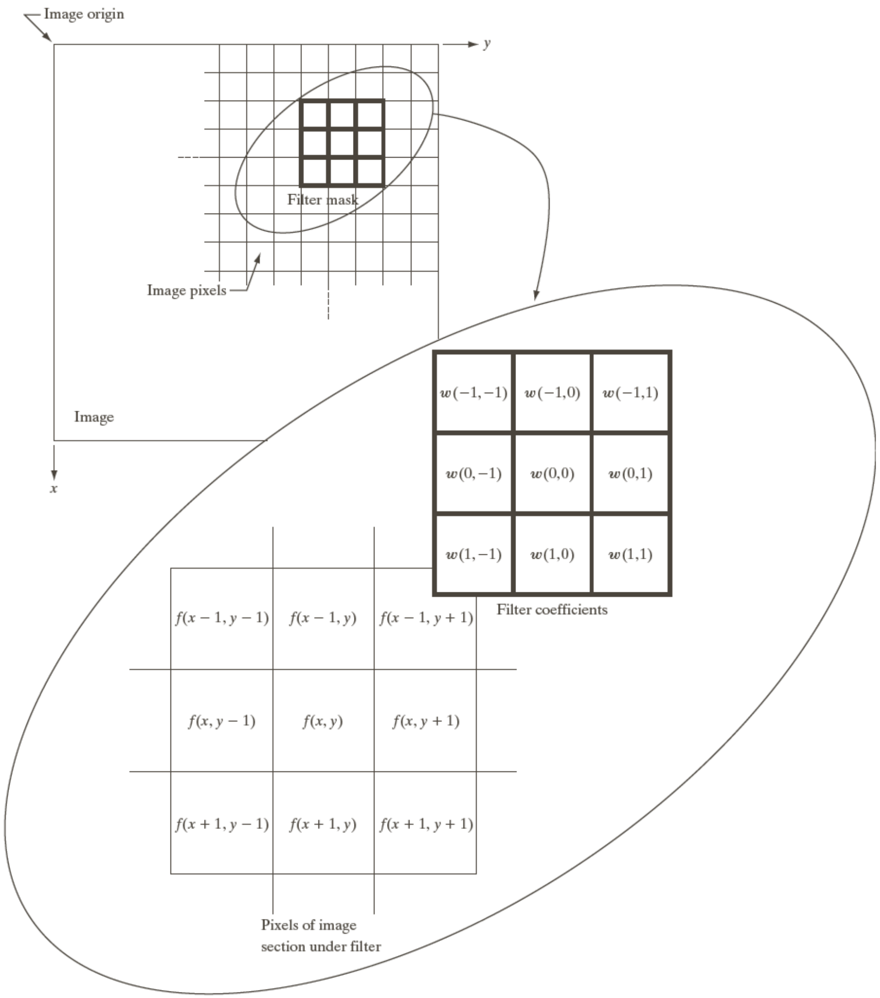
- Correlation operation
  - Filter superimposed on each pixel location
  - Evaluation of a weighted average
    - Pixel value
    - Filter weight



Correlation

- Correlation operation
- Suppose the filter dimensions are $m \times n$
  - $m = 2a + 1$
  - $n = 2b + 1$
- Correlation is defined as:

$$g(x,y) = \sum_{s=-a}^{s=a} \sum_{t=-b}^{t=b} w(s,t) I(x+s, y+t)$$



Signal convolution

- Recall: signal convolution

$$(f * g)(t) = \int_{-\infty}^{+\infty} f(\tau)g(t-\tau)d\tau$$

Convolution vs correlation

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$$(f * g)(t) = \int_{-\infty}^{+\infty} f(\tau)g(t-\tau)d\tau$$

- Applied to the image spatial domain

$$g(x, y) = \sum_{s=-a}^{s=a} \sum_{t=-b}^{t=b} w(s, t)I(x-s, y-t)$$

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- Compare with the definition of correlation

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Correlation vs convolution – notation

- In the CV context, convolution and correlation are often used as synonims
  - Usually, correlation is evaluated
    - But it is called convolution!
- Filters are usually symmetric
  - Convolution and correlation are equal
- Filters obtained by applying convolution are called **convolutional filters**

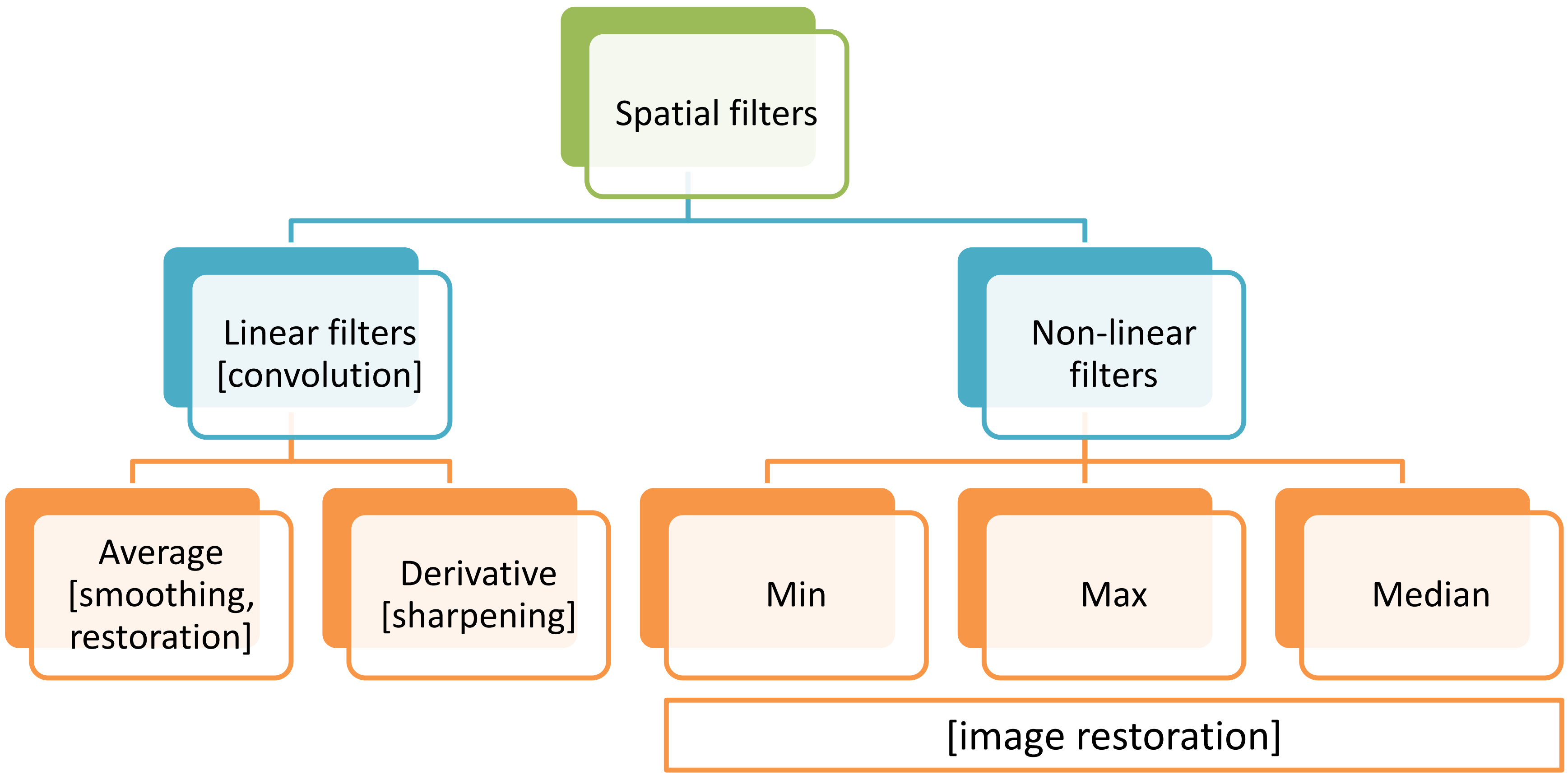
Effects on brightness

- **The filter weights can change the image brightness**
- Brightness is unchanged if:

$$\sum_i w_i = 1$$

- This is obtained by a normalization factor

Spatial filters overview



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