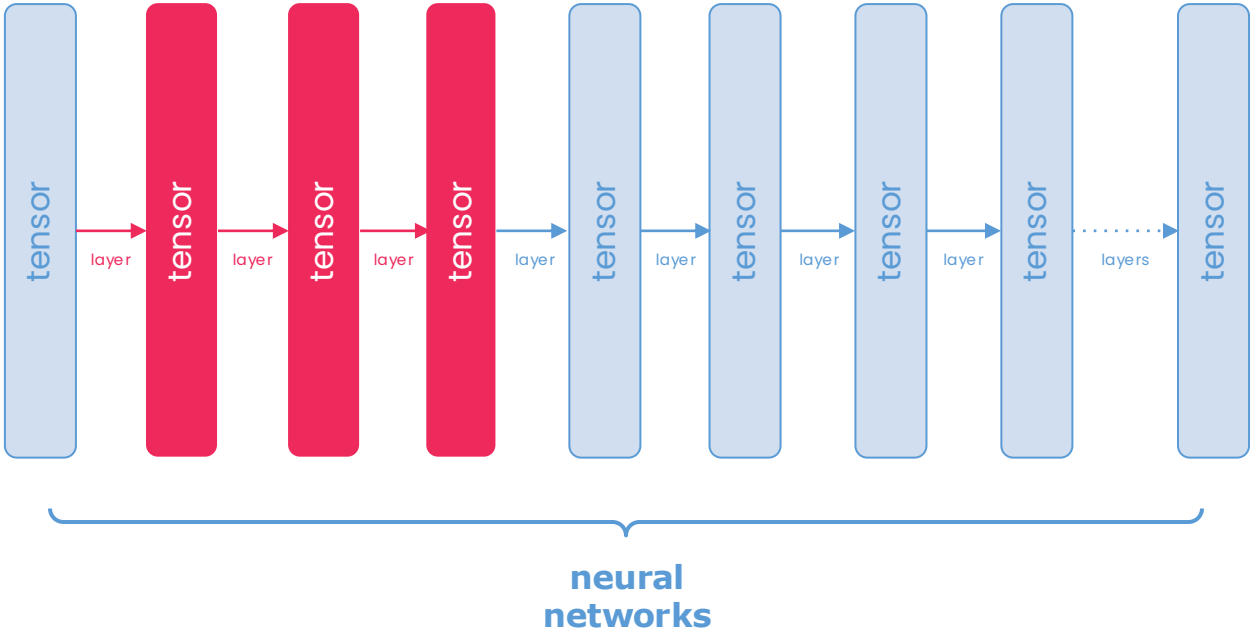
Insper

Computer Vision

# Class 6: Image Smoothing and Convolutional Filters


tensor
layer
tensor
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layers
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neural
networks

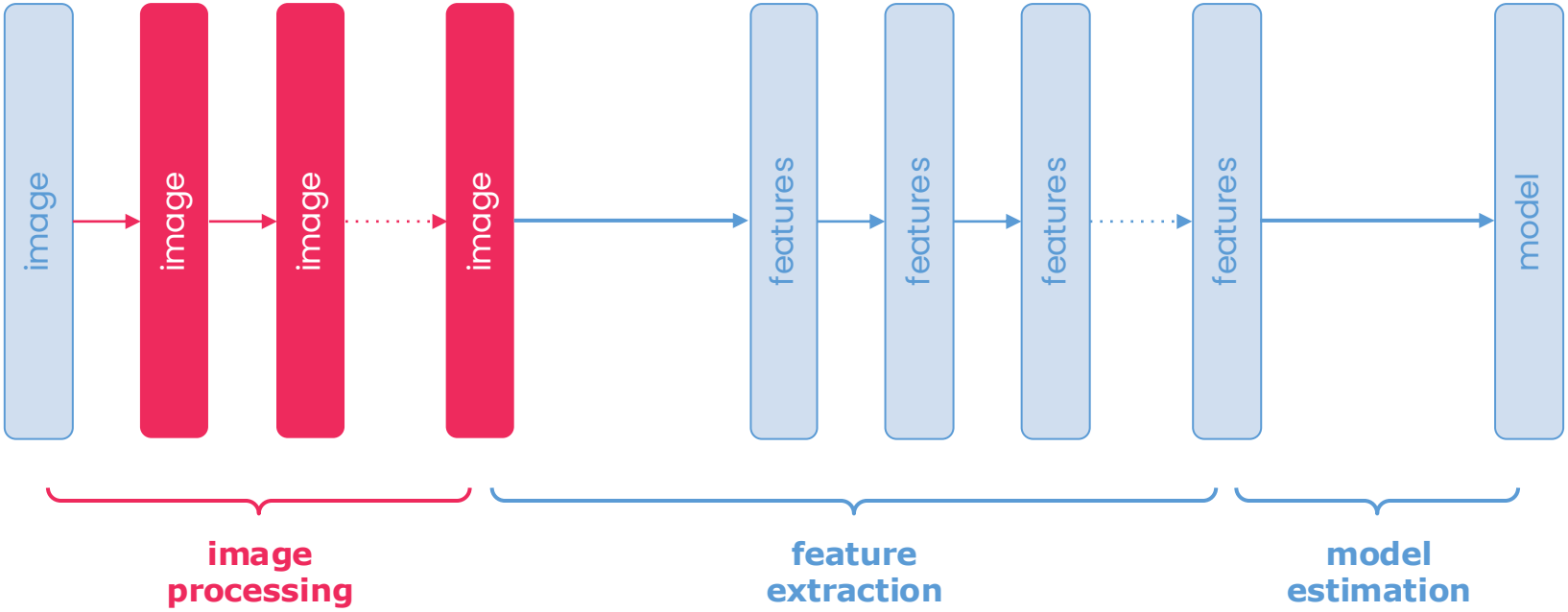


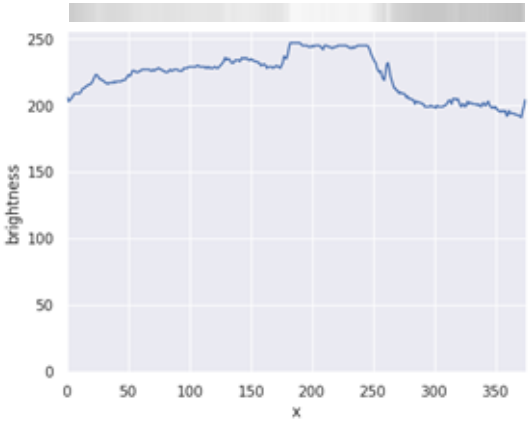
image
image
image
image
features
features
features
features
model
image processing
feature extraction
model estimation

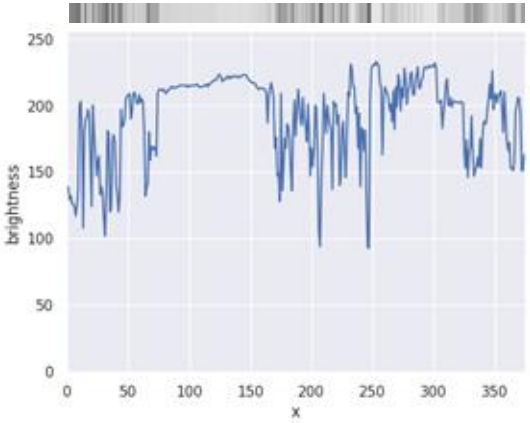
*We discussed how to enhance images to extract information...*

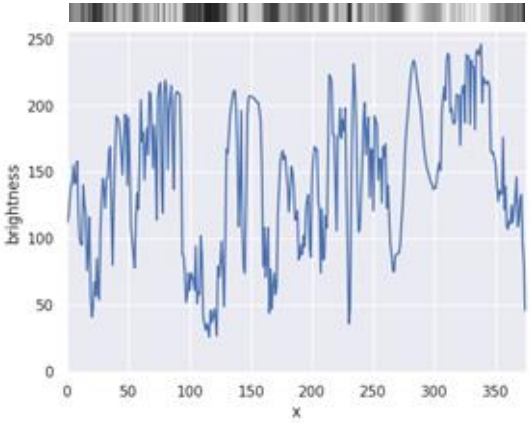
*...but assumed that data = information.*

**Gray level image:**
bivariate function from coordinates to levels

$$P(x, y)$$

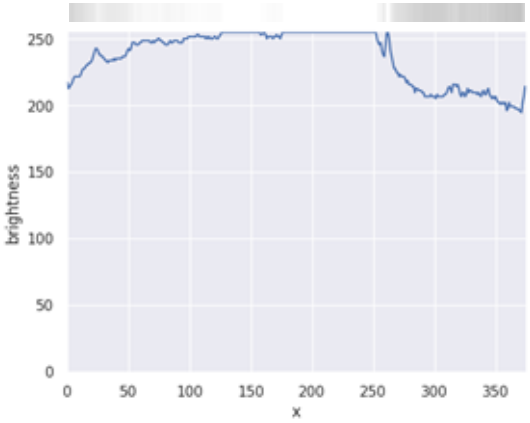


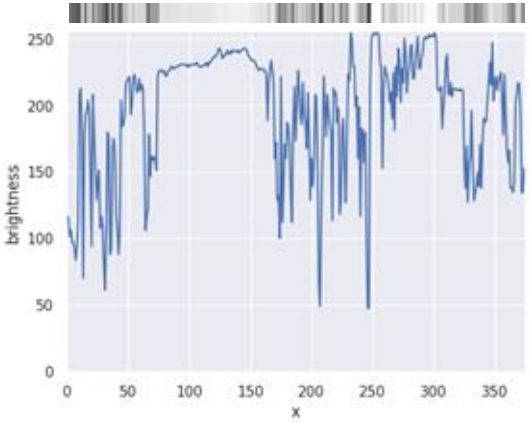



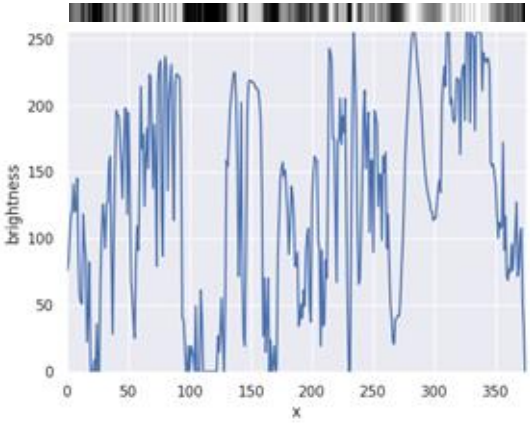



**Contrast:**
multiplicative constant,
but preserving the mean

$$1.5 \cdot (P(x,y) - \bar{p}) + \bar{p}$$



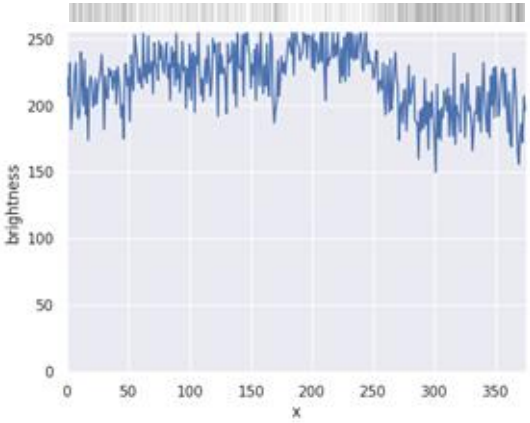



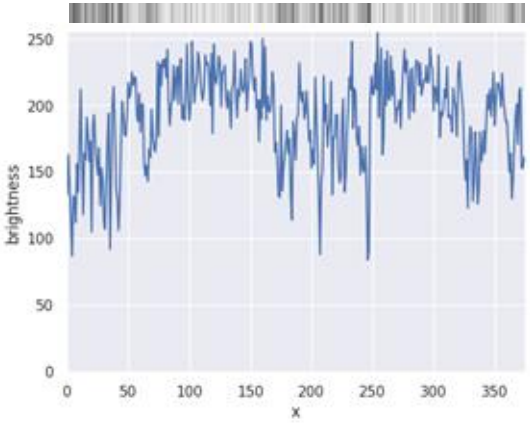
*Realistically, this is not true!*

*In most cases, we know that data = information + noise.*

**Image with noise:**
levels slightly below or above the correct value

$$P(x,y) + \epsilon(x,y)$$



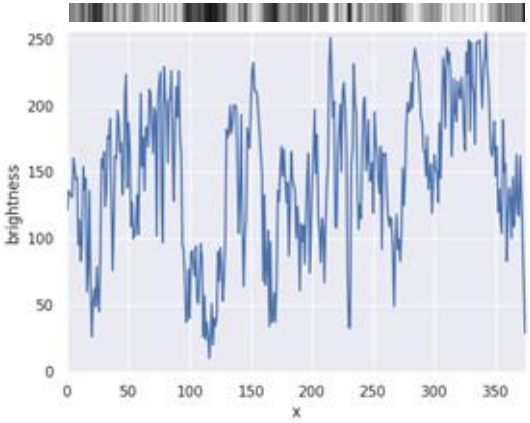
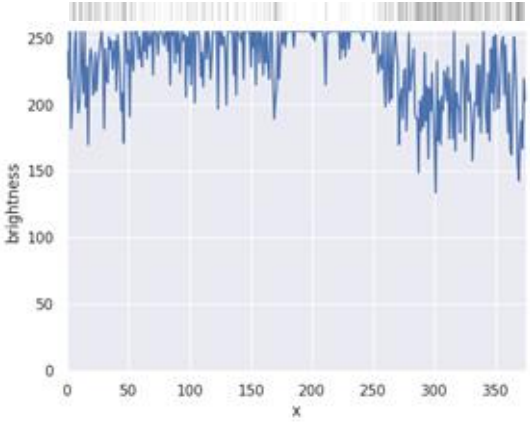
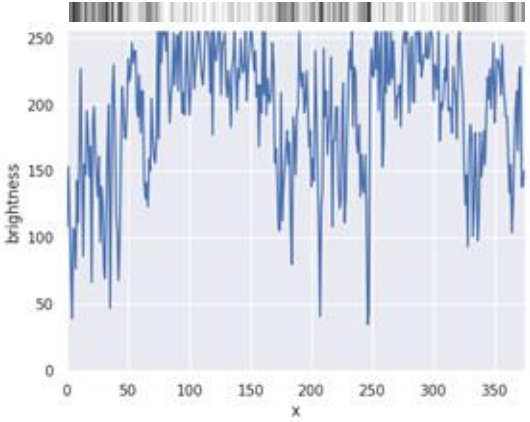
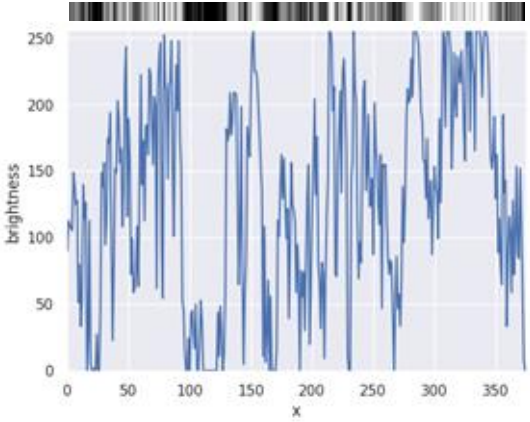



**Image with noise:**
increasing the contrast amplifies the problem

$$f_c(P(x,y) + \epsilon(x,y))$$

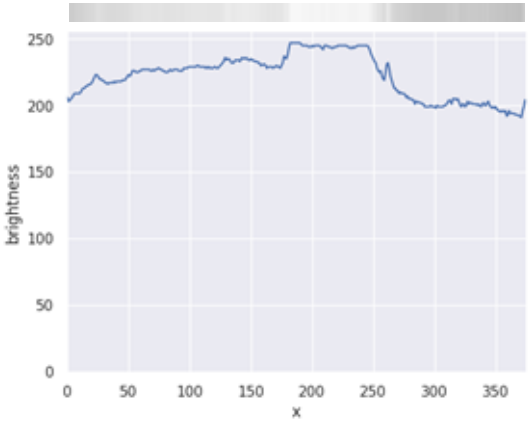


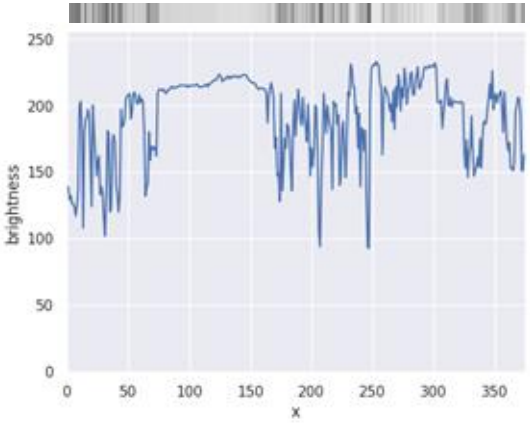



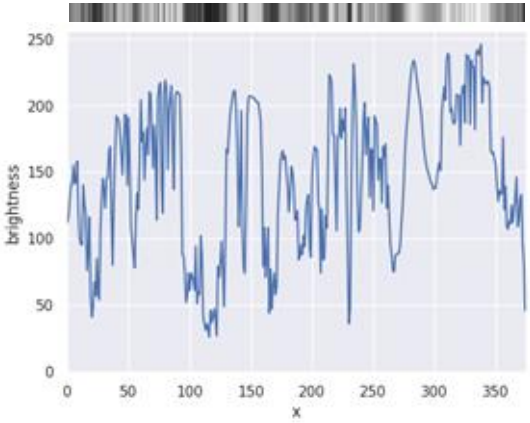



**Denoised image:**
usually not possible due to the loss of information

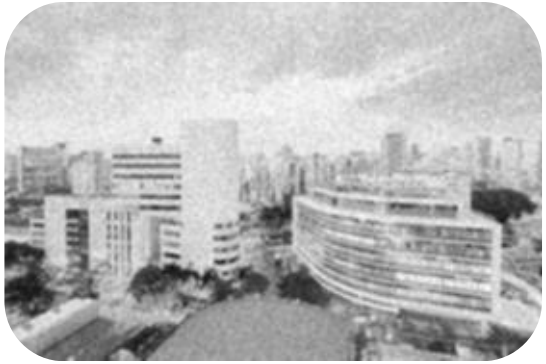
$$(P(x,y) + \epsilon(x,y)) - \epsilon(x,y)$$



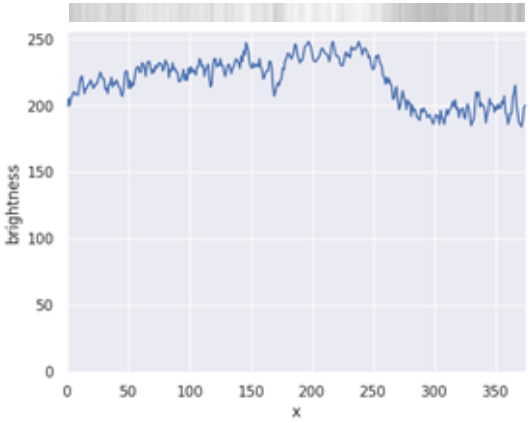



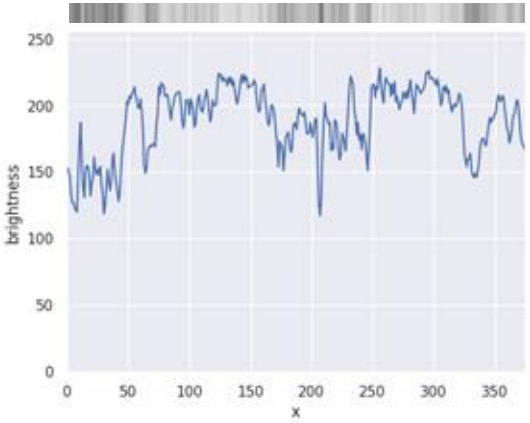



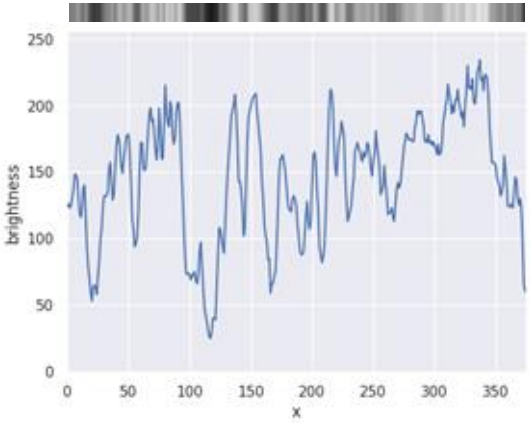
## Smoothed image?



$$f_s(P(x,y)+\epsilon(x,y))$$



## Signal smoothing:

for each value, the mean of a window around it

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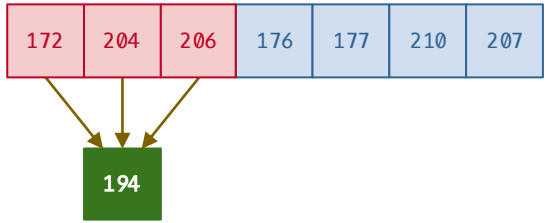
for each value, the mean of a window around it



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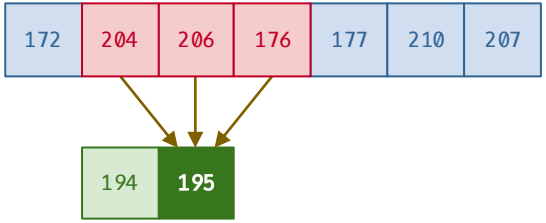

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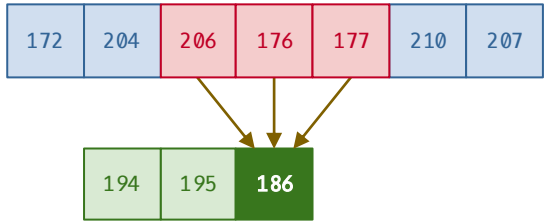
for each value, the mean of a window around it



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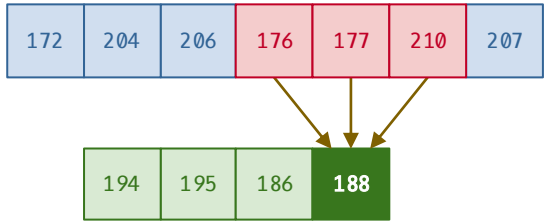

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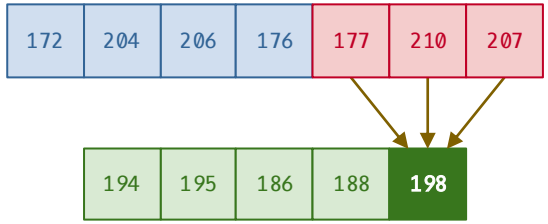

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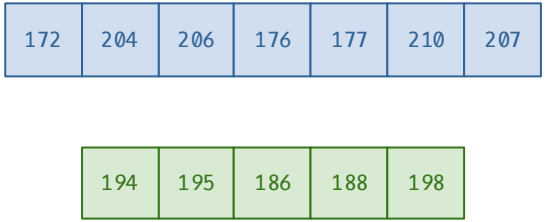
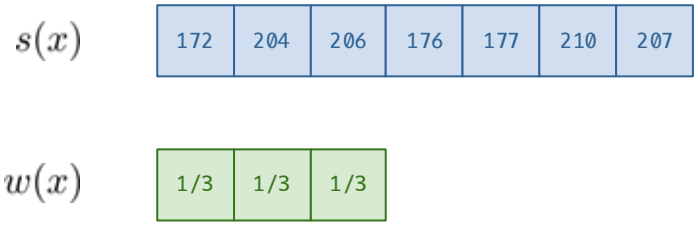


## Discrete convolution:

sum of the products with each possible shift of another function




*(technically, this is the definition of cross-correlation... we will explain more next class)*

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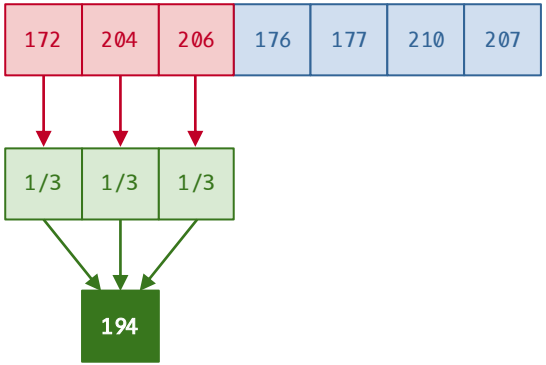
sum of the products with each possible shift of another function



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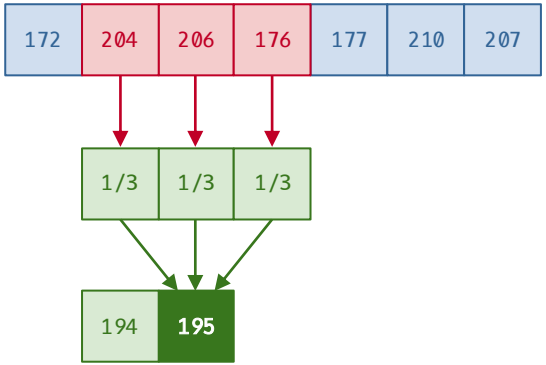

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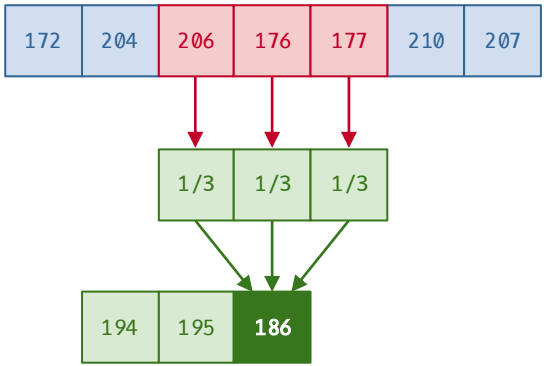

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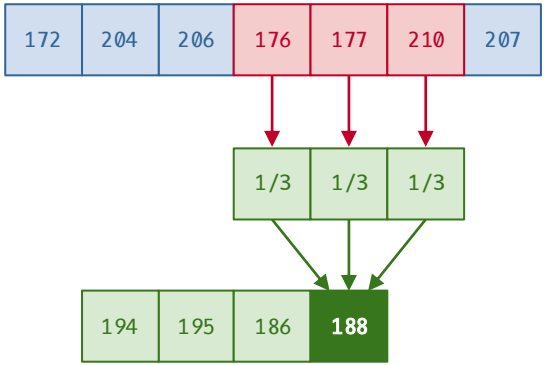

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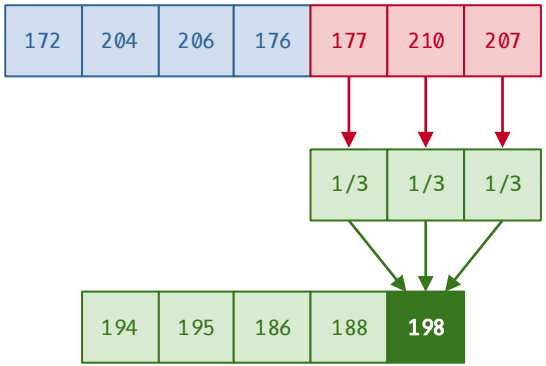


# Discrete convolution:

sum of the products with each possible shift of another function


$s$


$s * w$

# Discrete convolution:

sum of the products with each possible shift of another function

| | | | | | | |
|---|---|---|---|---|---|---|
| 179 | 191 | 236 | 152 | 192 | 191 | 155 |
| 114 | 188 | 179 | 159 | 190 | 193 | 232 |
| 172 | 204 | 206 | 176 | 177 | 210 | 207 |
| 156 | 217 | 184 | 174 | 205 | 197 | 148 |
| 122 | 179 | 174 | 169 | 214 | 255 | 180 |

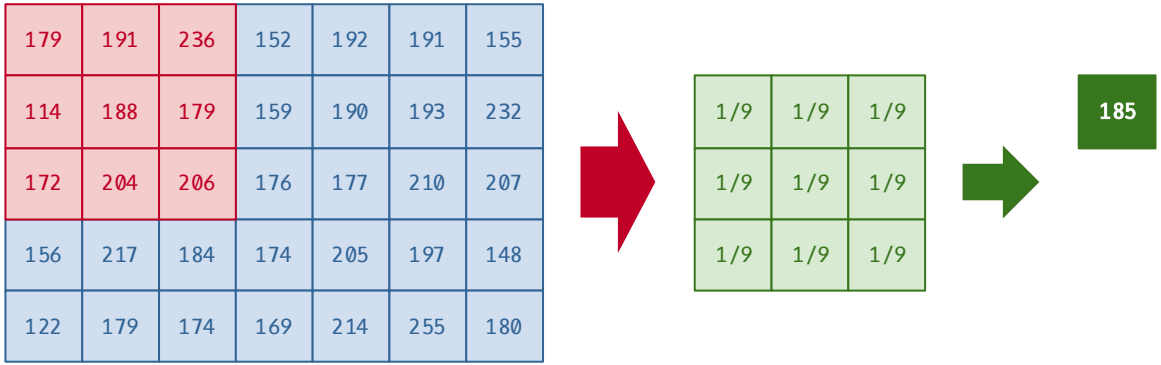
$P(x, y)$

| | | |
|---|---|---|
| 1/9 | 1/9 | 1/9 |
| 1/9 | 1/9 | 1/9 |
| 1/9 | 1/9 | 1/9 |

$W(x, y)$

# Discrete convolution:

sum of the products with each possible shift of another function



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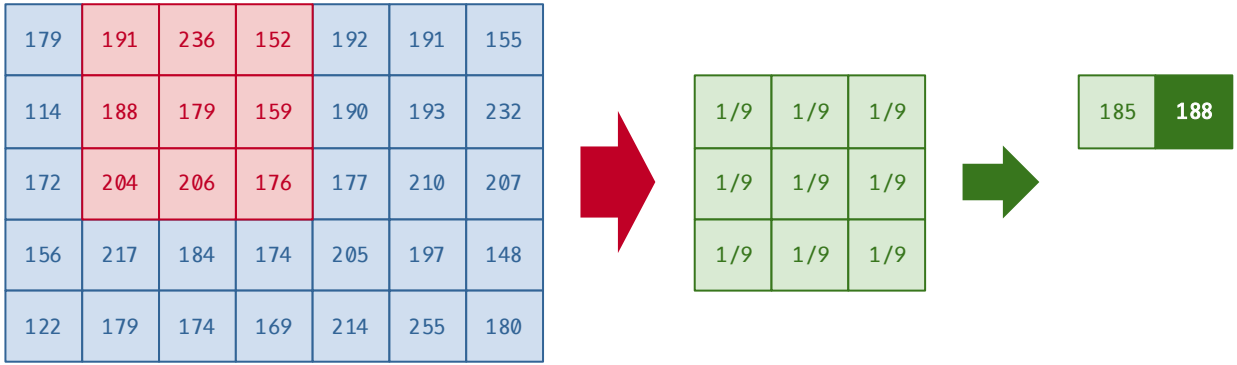

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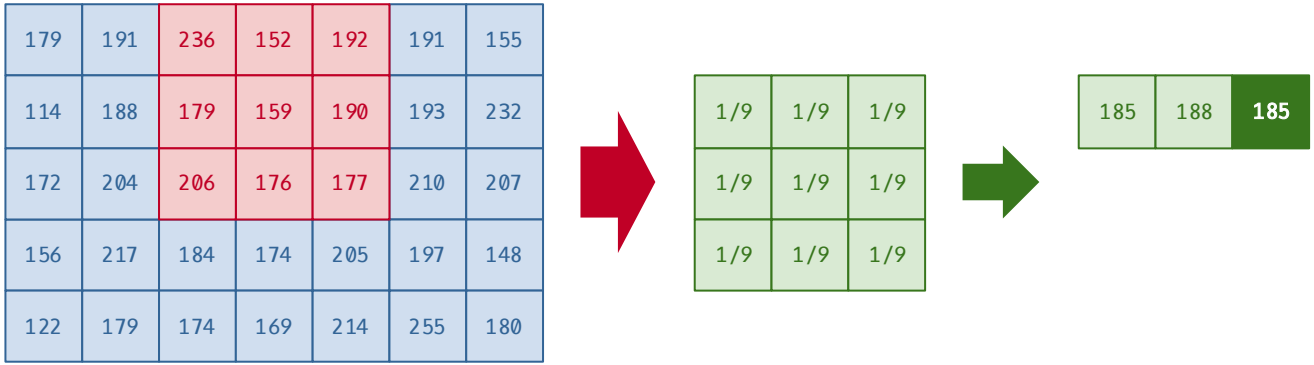

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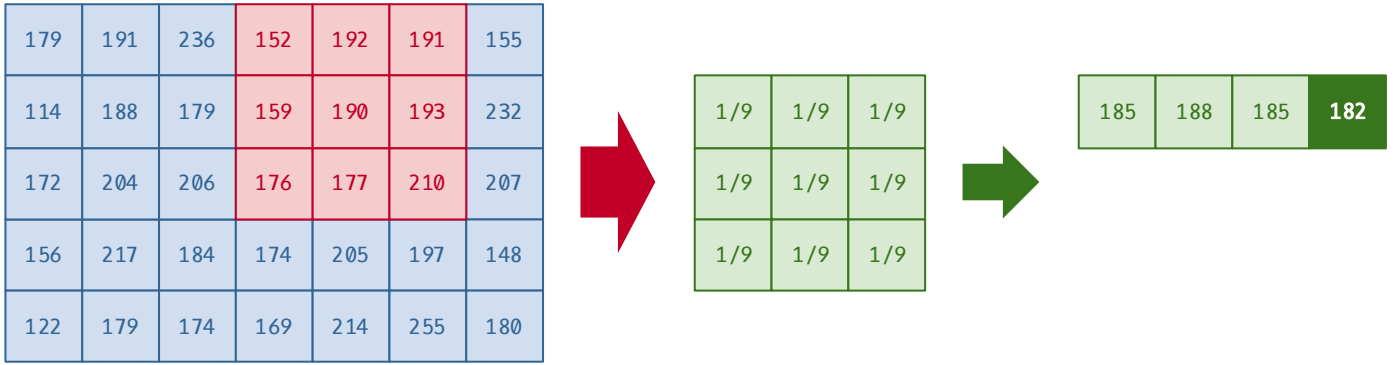

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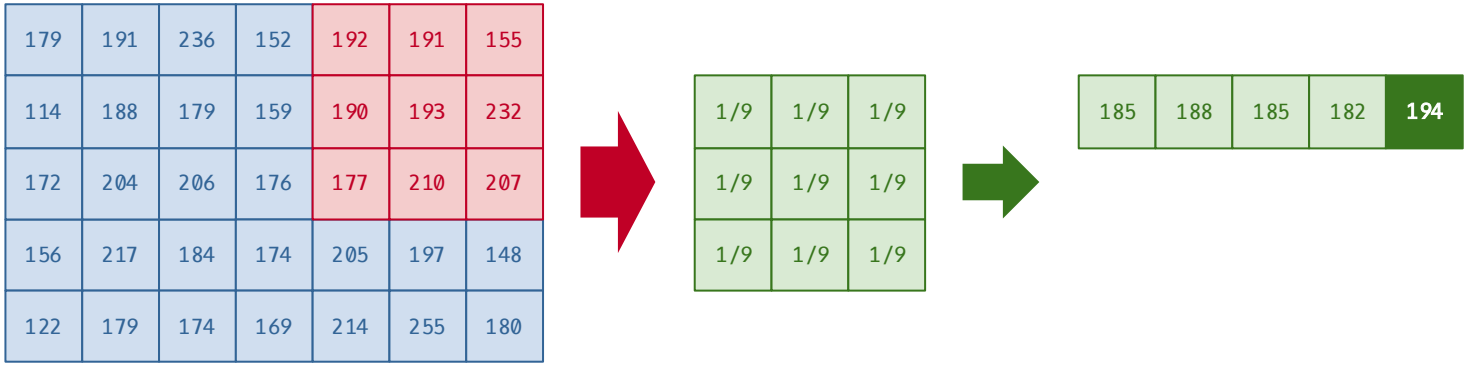

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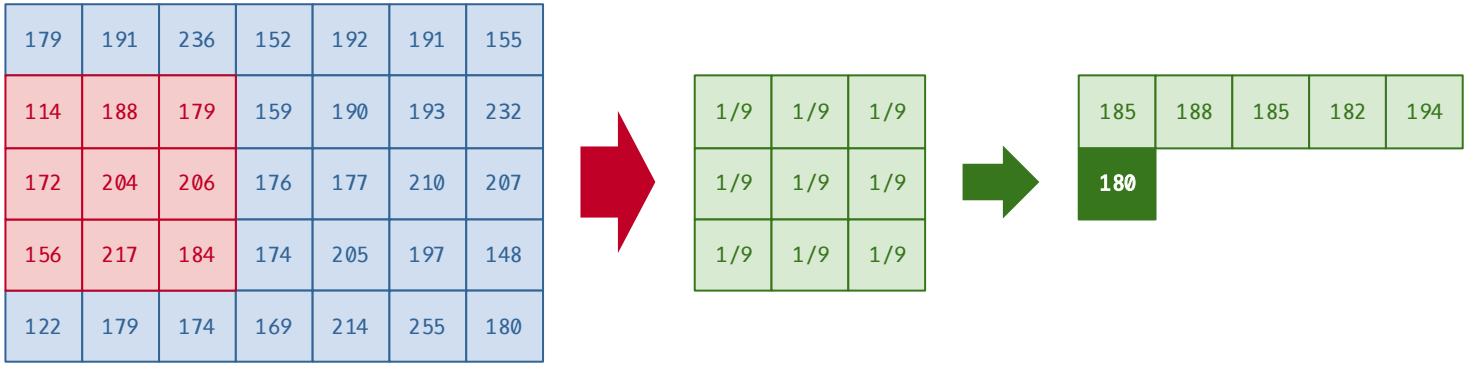

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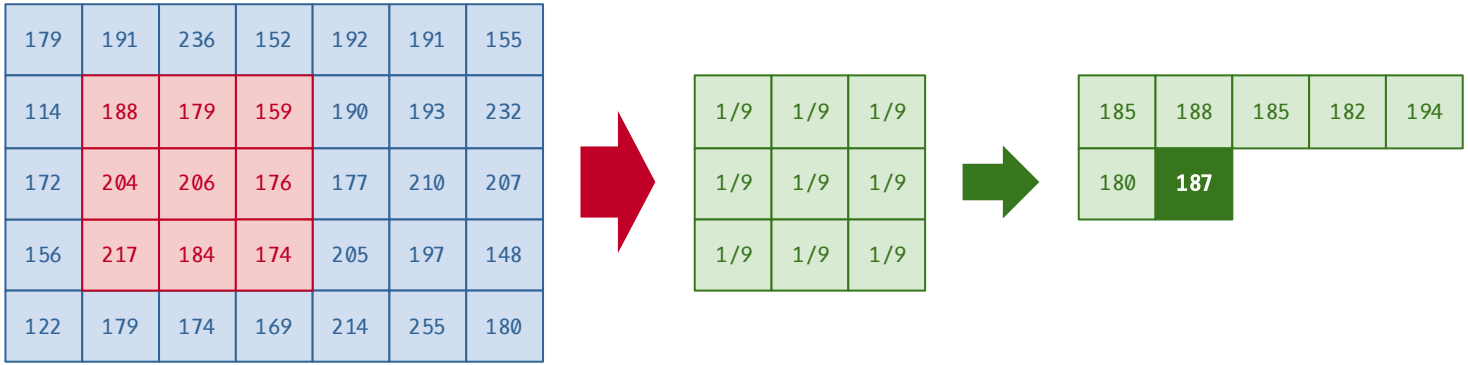

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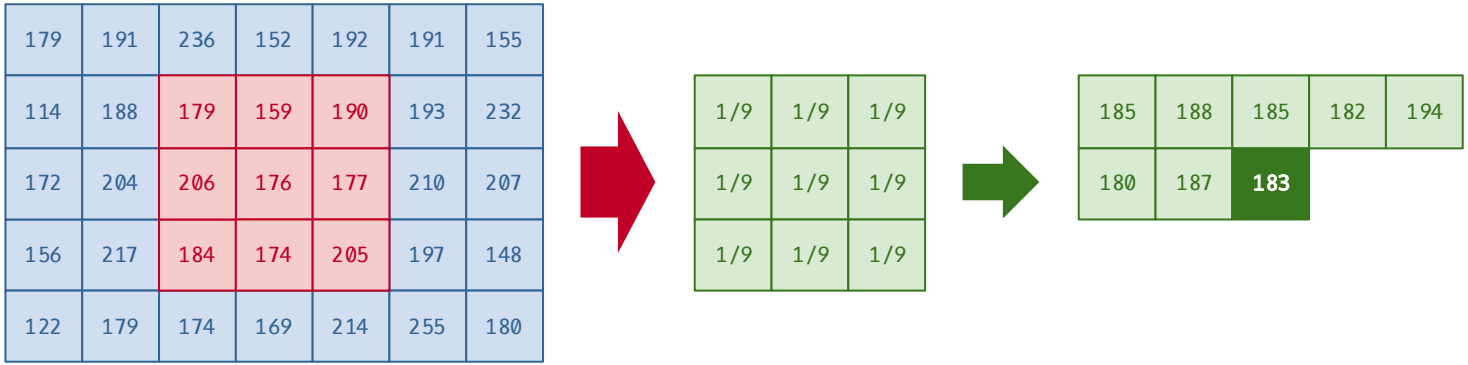

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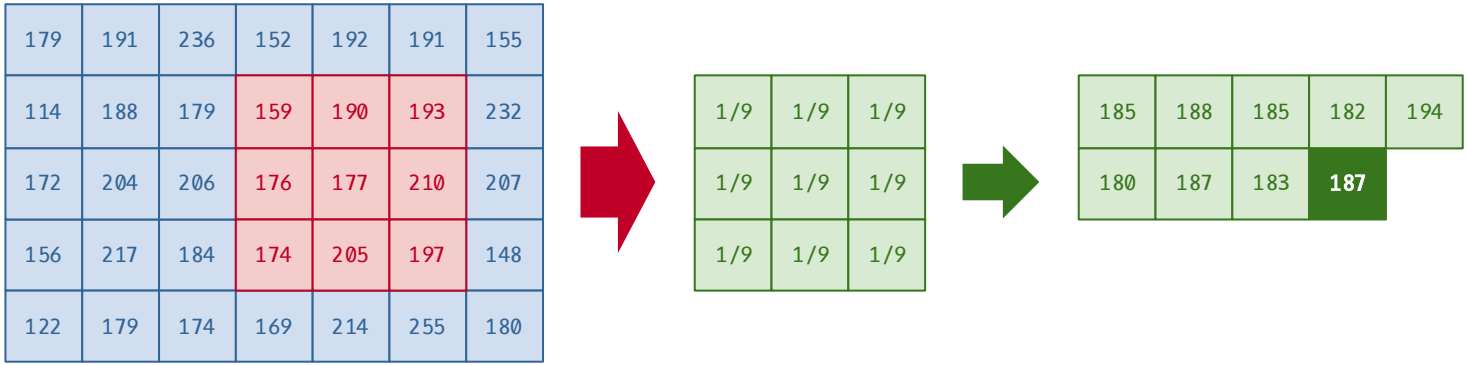

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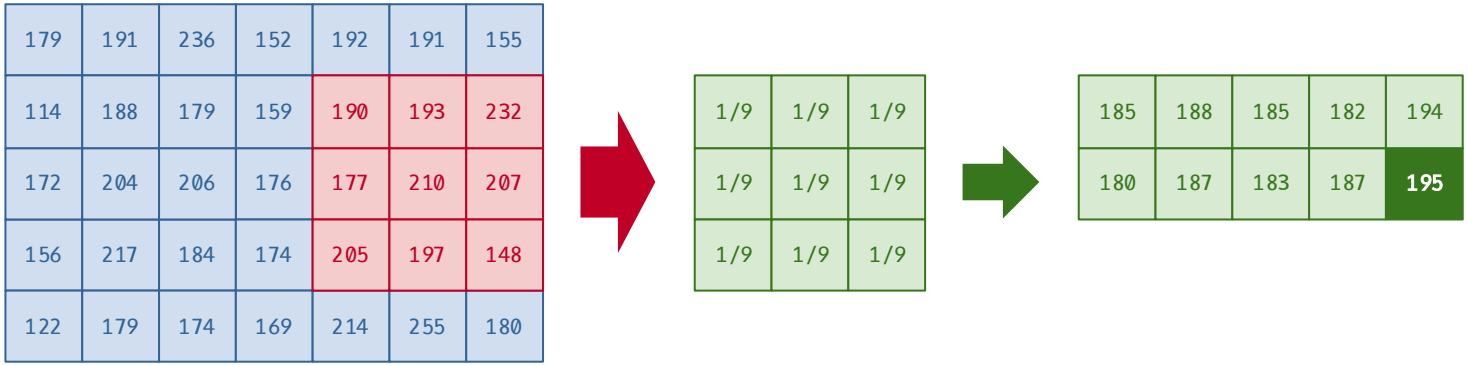

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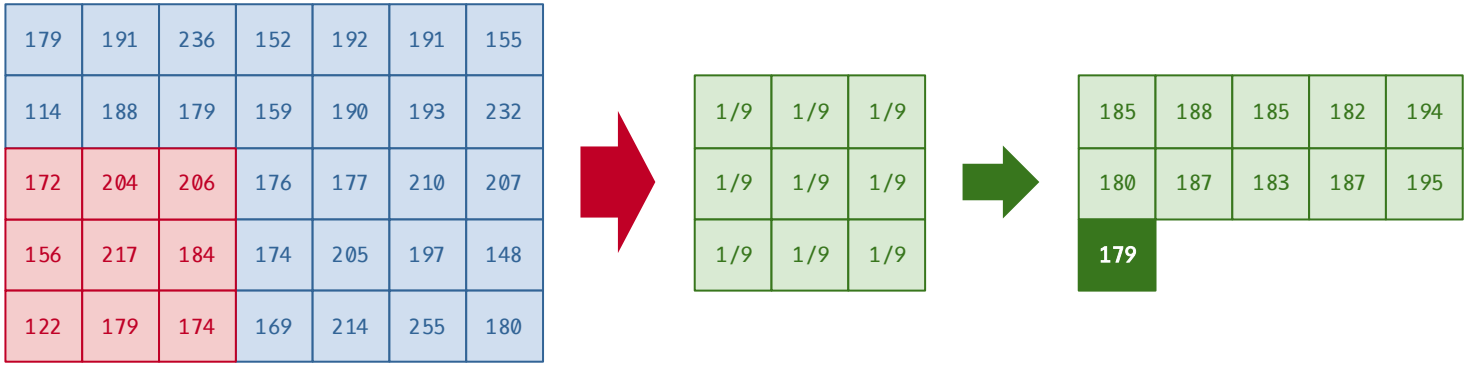
sum of the products with each possible shift of another function



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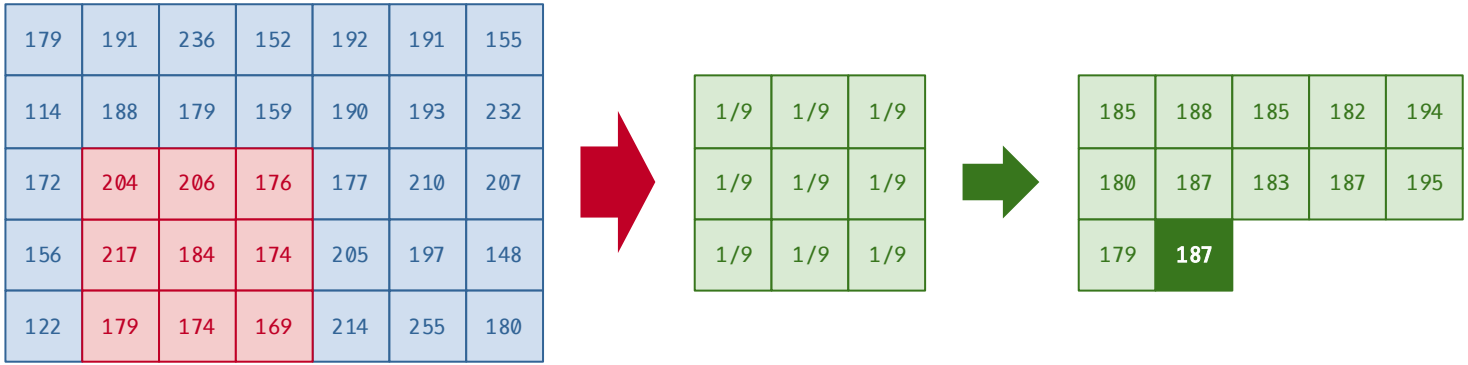
sum of the products with each possible shift of another function



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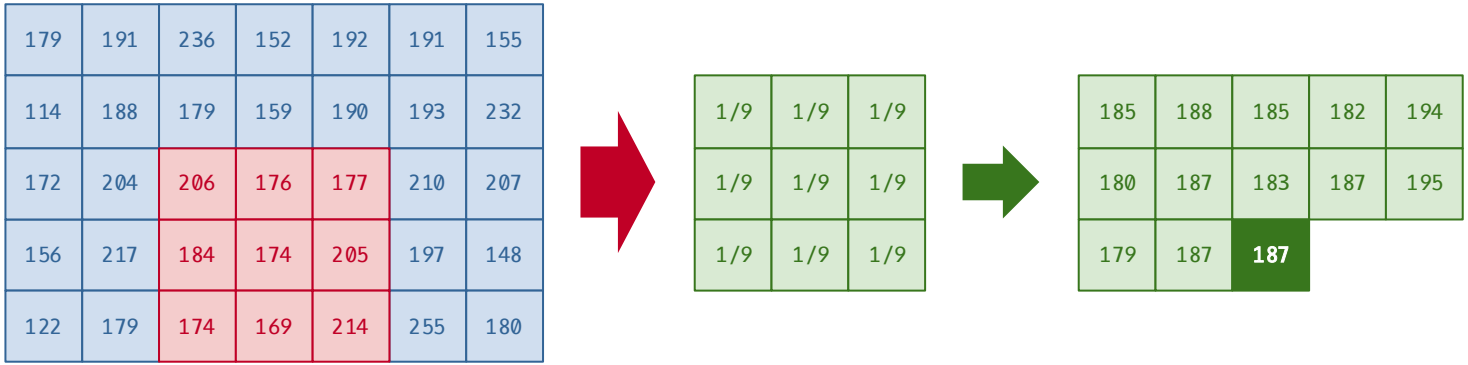
sum of the products with each possible shift of another function



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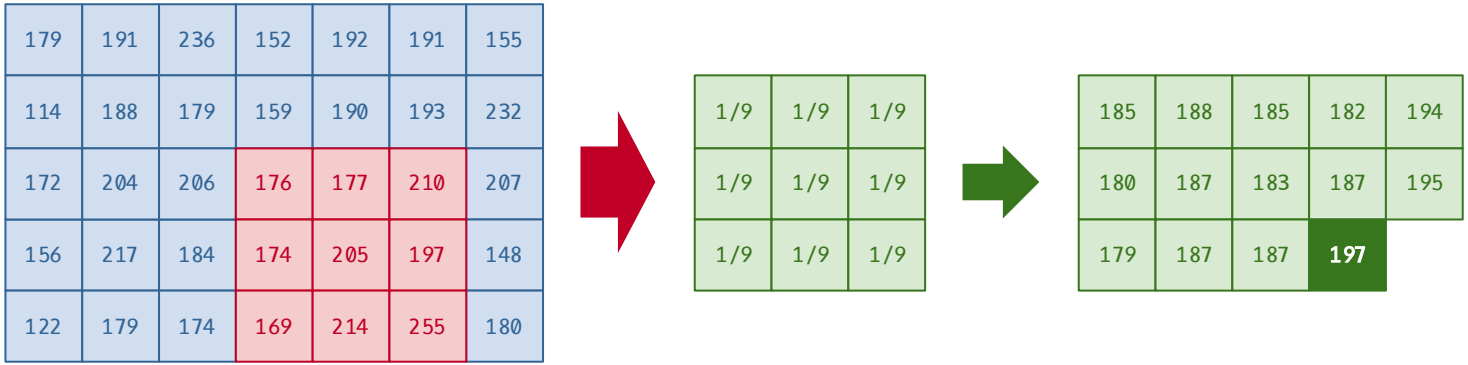
sum of the products with each possible shift of another function



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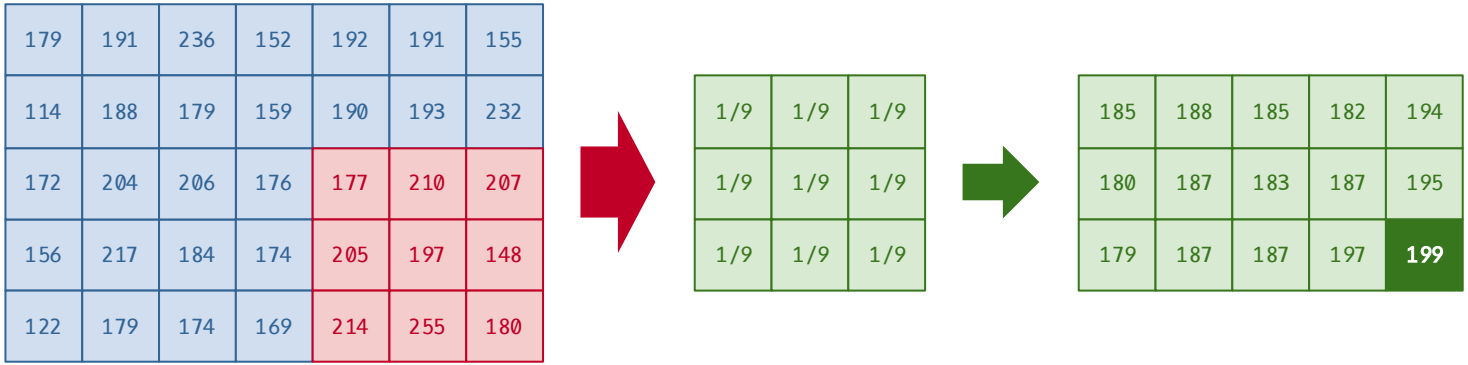


# Discrete convolution:

sum of the products with each possible shift of another function

| | | | | | | |
|---|---|---|---|---|---|---|
| 179 | 191 | 236 | 152 | 192 | 191 | 155 |
| 114 | 188 | 179 | 159 | 190 | 193 | 232 |
| 172 | 204 | 206 | 176 | 177 | 210 | 207 |
| 156 | 217 | 184 | 174 | 205 | 197 | 148 |
| 122 | 179 | 174 | 169 | 214 | 255 | 180 |

$P$

| | | | | |
|---|---|---|---|---|
| 185 | 188 | 185 | 182 | 194 |
| 180 | 187 | 183 | 187 | 195 |
| 179 | 187 | 187 | 197 | 199 |

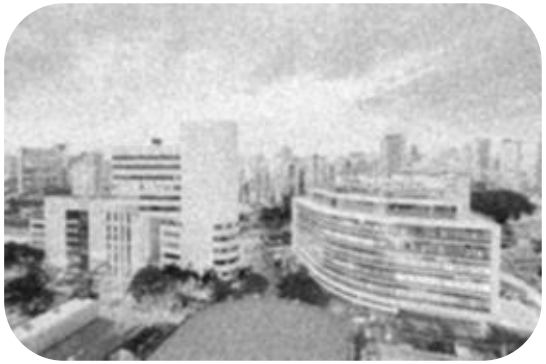
$P * W$

# Image smoothing:
convolution with a kernel of weights

$P$

| | | |
|---|---|---|
| 1/9 | 1/9 | 1/9 |
| 1/9 | 1/9 | 1/9 |
| 1/9 | 1/9 | 1/9 |

$W$



$P * W$

# Image smoothing:
convolution with a kernel of weights

$P$

| | | | | |
|---|---|---|---|---|
| 1/25 | 1/25 | 1/25 | 1/25 | 1/25 |
| 1/25 | 1/25 | 1/25 | 1/25 | 1/25 |
| 1/25 | 1/25 | 1/25 | 1/25 | 1/25 |
| 1/25 | 1/25 | 1/25 | 1/25 | 1/25 |
| 1/25 | 1/25 | 1/25 | 1/25 | 1/25 |

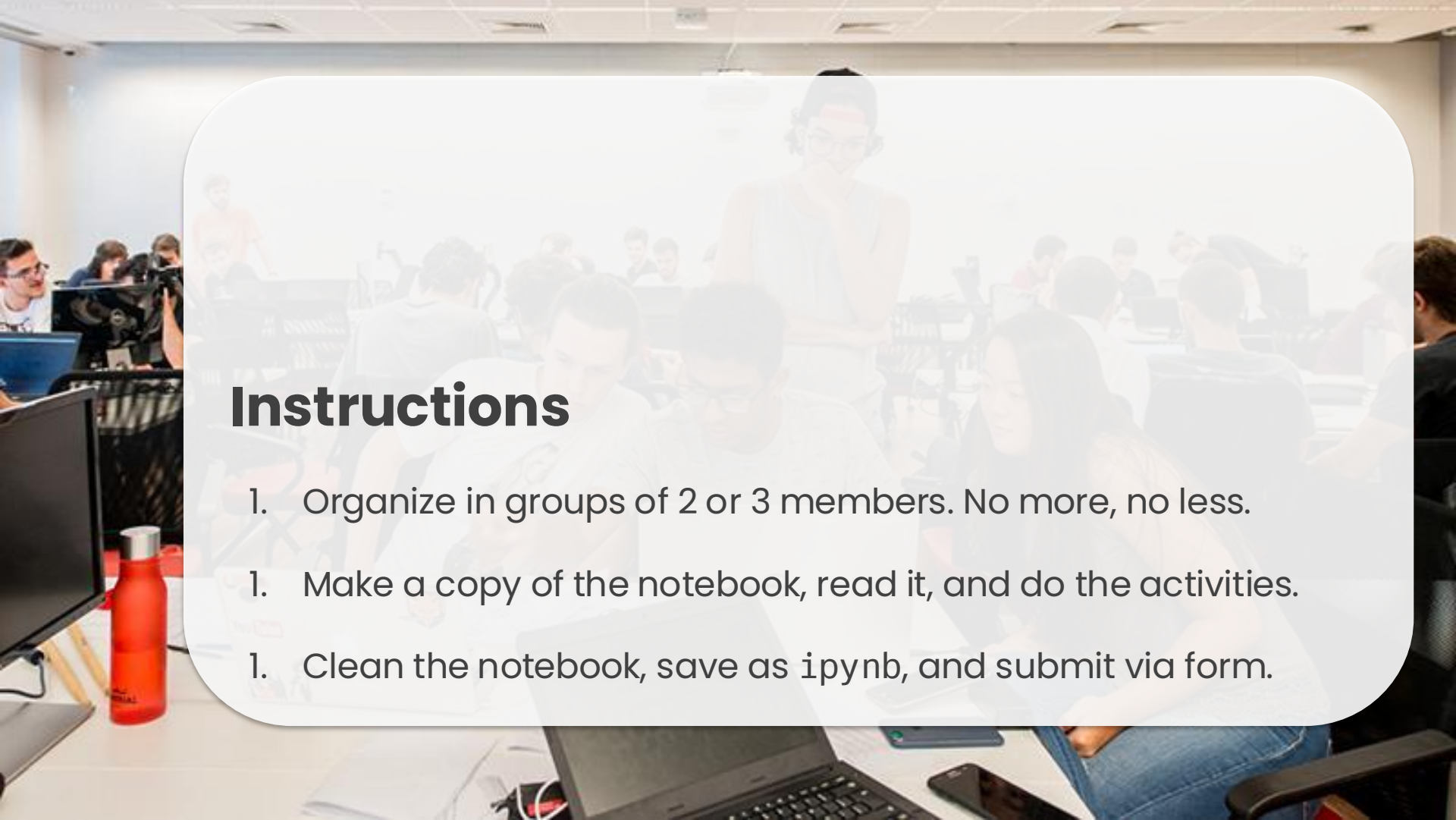
$W$

$P * W$

handout

# Toolkit

- **Language:** Python
- **Library:** OpenCV
- **Platform:** Google Colab

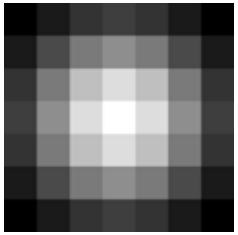


## Instructions

1. Organize in groups of 2 or 3 members. No more, no less.
1. Make a copy of the notebook, read it, and do the activities.
1. Clean the notebook, save as `ipynb`, and submit via form.

# Image smoothing:
convolution with a kernel of weights

$P$



$G$

$S = P * G$

# Next class:

- edge detection.

# Credits

This material was based on the work of other professors, listed below.

- Fabio Miranda (fabiomiranda@insper.edu.br)
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Well, except for the errors. Any errors you might find are probably my fault.

# Images

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