IDATG2206
Introduction to Spatial Filtering

Correlation, Convolution, Template Matching

Spatial filtering

- Many-to-one instead of one-to-one mappings (point transformations).
- A pixel is transformed through a linear combination of its **neighbours**.
- Key operations: convolution and correlation
- Examples from 1D to 2D

Correlation

- Let’s take a 1D case.

5	4	2	3	7	4	6	5	3	6

- Let’s suppose we want to replace each pixel with the average of its neighbours.
- What about the first and last elements (boundaries)?
  - Padding with zeros

.	.	.	*0*	*0*	5	4	2	3	7	4	6	5	3	6	*0*	*0*	.	.	.

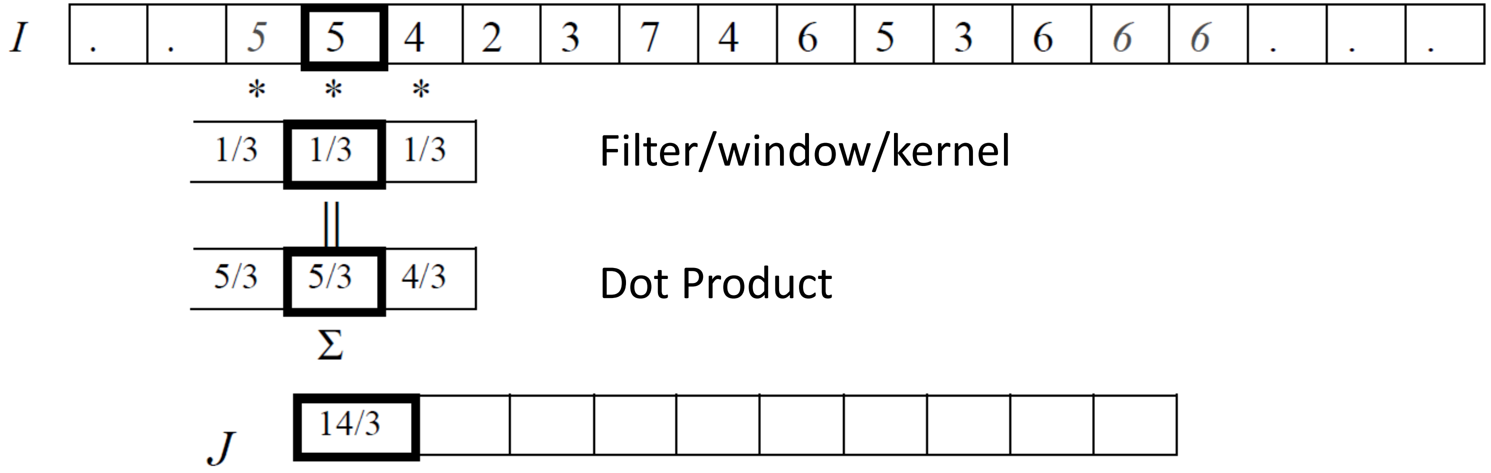
  - Replicate the first and last elements

.	.	.	*5*	*5*	5	4	2	3	7	4	6	5	3	6	*6*	*6*	.	.	.

  - Assume cyclic repetition of elements

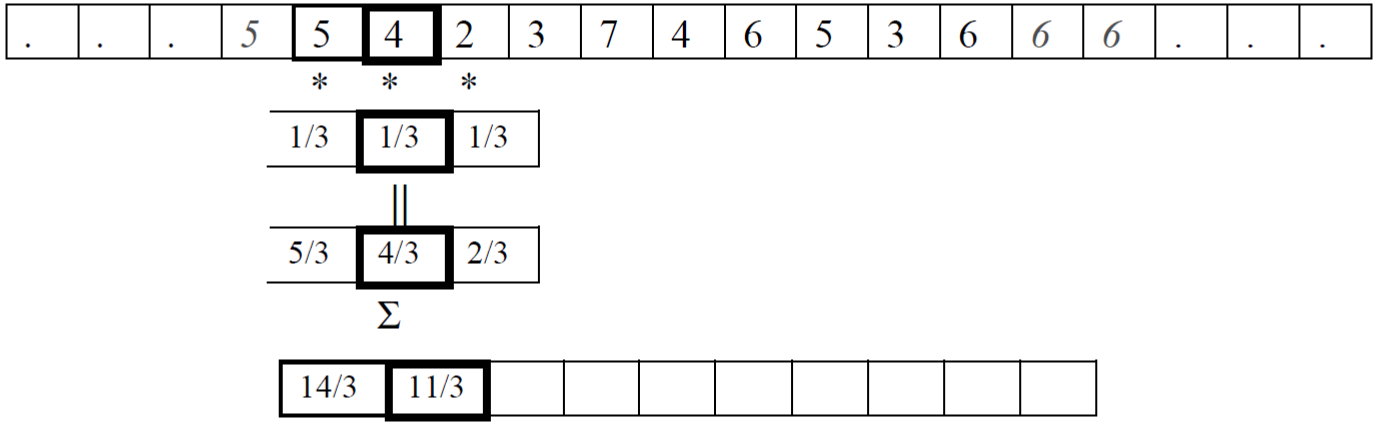
.	.	.	*3*	*6*	5	4	2	3	7	4	6	5	3	6	*5*	*4*	.	.	.

Correlation as a Windowed Operation



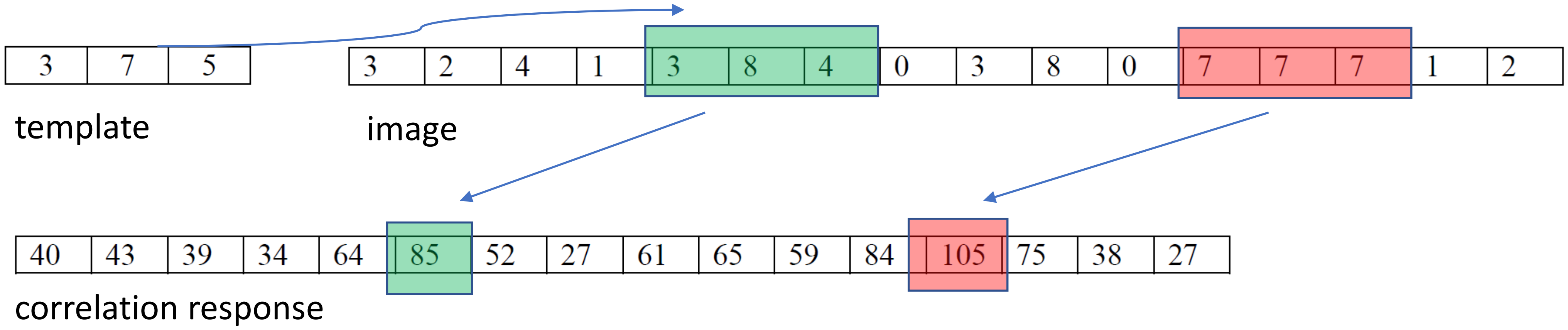
We apply the same operation to all pixels → **shift-invariant**

Sliding/moving the filter to the next pixel

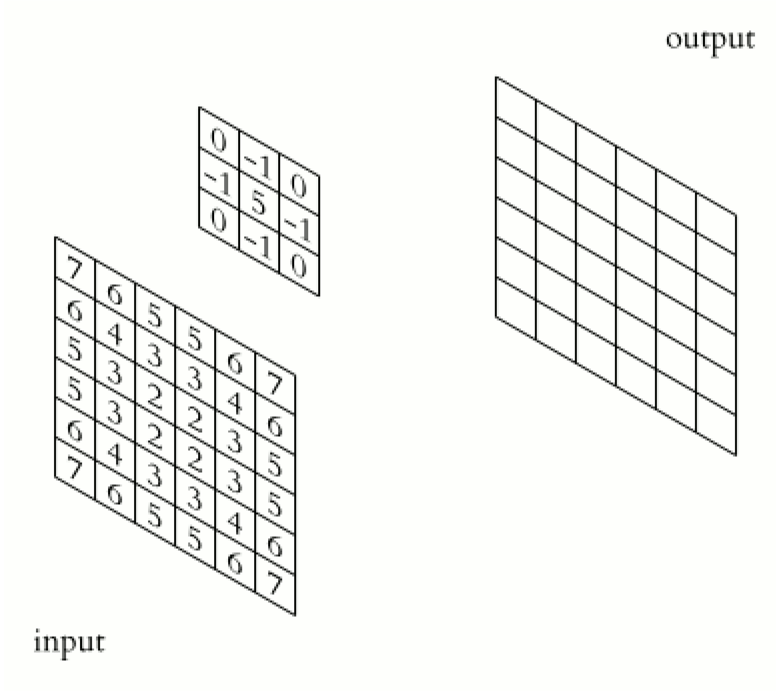


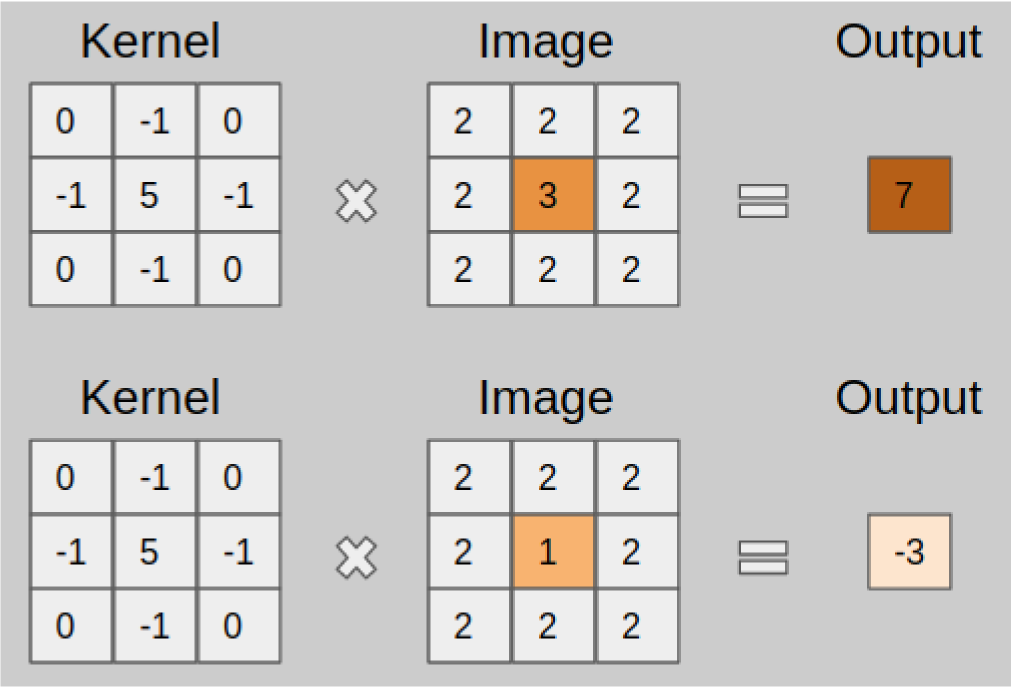
Template matching with correlation

- The template can be seen as a filter.
- The correlation result can be seen as a response. The higher the response, the higher the match.
- However, sometimes, we might get high response when the input has high intensities.
- Therefore, some additional operations are applied to the correlation response: sum of squared differences, **normalized cross-correlation**.



Correlation in 2D





This type of kernel increases the contrast and sharpens the image.

Image Source: https://towardsdatascience.com/types-of-convolution-kernels-simplified-f040cb307c37

Correlation vs. convolution

- Technically, convolution is a “flipped correlation”.
- In 2D, we flip the filter both horizontally and vertically.
- Mathematically, the key difference between the two is that convolution is associative.
- If F, G filters, then $F*(G*I) = (F*G)*I.$
- In practice, convolution is used for image processing operations (e.g. smoothing) and when we might want to apply a series of filters (so we are interested in the associative property)…
- …While correlation is used for template matching.
- When the filters are symmetric, convolution is equal to correlation.
- Both convolution and correlation are *shift-invariant*, so they are applied to each pixel in the image.

The "Convolution" in Convolutional Neural Networks

- Many neural network libraries implement the correlation operation, even if by **convention**, they call it convolution.
- In many CNNs, flipping or not the kernel doesn't make a difference.