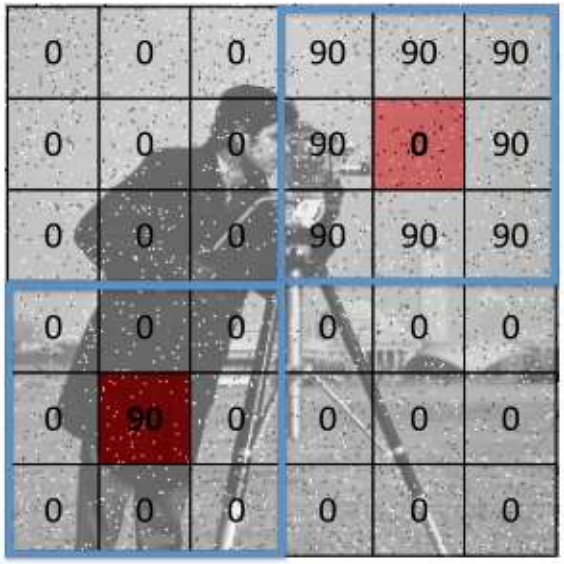
Learning Objectives

- Learn to perform image filtering through cross-correlation and convolution operations
- Learn some uses for these operations in context of image understanding

Image Filtering

Image Filtering



$$G[u,v] = \frac{1}{(2k+1)^2} \sum_{i=-k}^{k} \sum_{j=-k}^{k} I[u-i, v-j]$$

$$G = \frac{1}{(2\times 1+1)^2}[8\times 90 + 0] = 80$$

$$G = \frac{1}{(2\times 1+1)^2}[8\times 0 + 90] = 10$$

(2k+1): Filter size

(u, v): Center pixel coordinates

Cross-Correlation

$$G[u,v] = \sum_{i=-k}^{k} \sum_{j=-k}^{k} H[i,j] I[u-i, v-j]$$

Mean Filter

$$H = 1/9 \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Gaussian Filter

$$H = 1/16 \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

Cross-Correlation

Mean Filter

Gaussian Filter

Convolution

- A convolution is a cross-correlation where the filter **is flipped both horizontally and vertically** before being applied to the image

$$H = \begin{array}{|c|c|c|}\hline a & b & c \\ \hline d & e & f \\ \hline g & h & i \\ \hline \end{array}$$

$$G[u,v] = \sum_{i=-k}^{k} \sum_{j=-k}^{k} H[i,j] I[u-i, v-j]$$

$$\begin{array}{|c|c|c|}\hline i & h & g \\ \hline f & e & d \\ \hline c & b & a \\ \hline \end{array}$$

Convolution

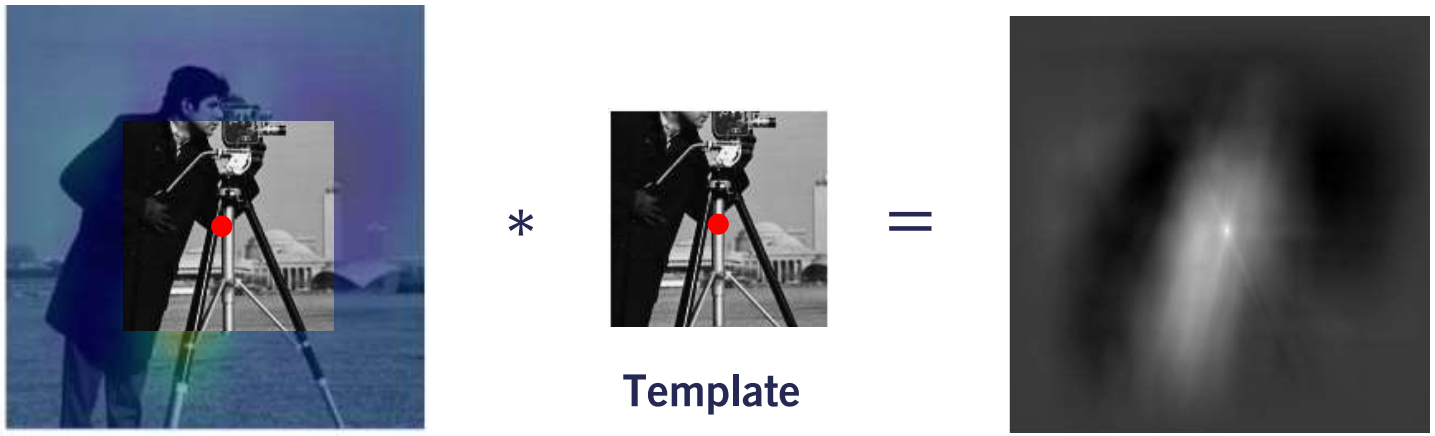
- Unlike Cross-Correlation, Convolution is associative. If H and F are filter kernels then:

$$H * (F * I) = (H * F) * I$$

- Precompute filter convolutions $(H * F)$ then apply it once to the image to reduce runtime!

Applications: Template Matching

- **Cross-correlation** is useful for template matching
- The pixel with the **highest response** from Cross-correlation is the location of the template in an **image**



Applications: Gradient Computation

- **Convolution** can be used for Image gradient computation
- Define a finite difference kernel, and apply it to the image to get the image gradient

$*$

1	2	1
0	0	0
-1	-2	-1

Horizontal Sobel Kernel

$=$

Summary

- Cross-Correlation and Convolution are two operations that can be used to apply a filter to an image
- Cross-Correlation can be used to match image regions, while convolutions can be used for edge detection
- **Next: Image Features**

Module Summary

You learned…

- How to represent a digital image,
- How points in 3D relate to pixels in an image
- To compute 3D point coordinates from a pair images,
- To process images using cross-correlation and convolution operations.

This week's assignment: Stereo-based distance to impact