

Image Filtering

Course 3, Module 1, Lesson 4



UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

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



Copyright Massachusetts Institute of Technology

Image Filtering

0	0	0	90	90	90
0	0	0	90	0	90
0	0	0	90	90	90
0	0	0	0	0	0
0	90	0	0	0	0
0	0	0	0	0	0

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

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

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

(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

$$H = 1/9$$

1	1	1
1	1	1
1	1	1

Gaussian Filter

$$H = 1/16$$

1	2	1
2	4	2
1	2	1

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

$$H = \begin{array}{|c|c|c|} \hline a & b & c \\ \hline d & e & f \\ \hline g & h & i \\ \hline \end{array} \quad G[u, v] = \sum_{i=-k}^k \sum_{j=-k}^k H[i, j] I[u-i, v-j]$$

i	h	g
f	e	d
c	b	a

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**

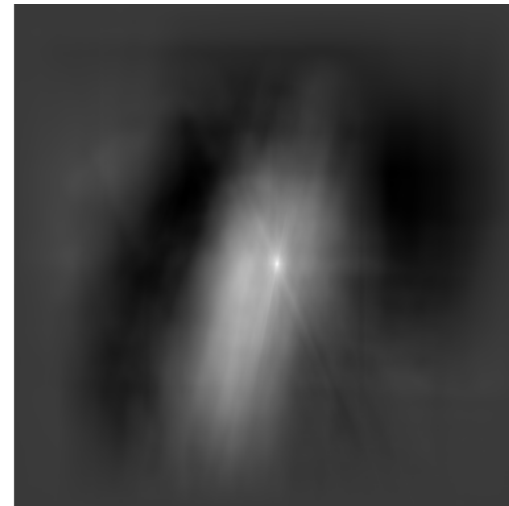


*



Template

=



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