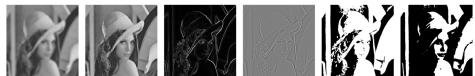




CPSC 425: Computer Vision



Lecture 3: Image Filtering

(unless otherwise stated slides are taken or adopted from **Bob Woodham**, **Jim Little** and **Fred Tung**)

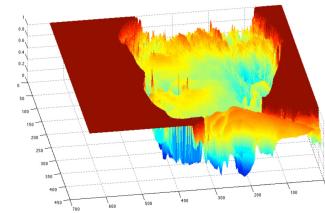
Image as a 2D Function

A (grayscale) image is a 2D function



grayscale image

$I(X, Y)$



Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Adding two Images

Since images are functions, we can perform operations on them, e.g., **average**



$I(X, Y)$



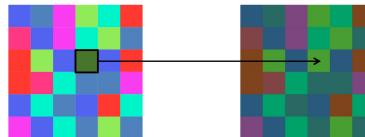
$G(X, Y)$



$$\frac{I(X, Y)}{2} + \frac{G(X, Y)}{2}$$

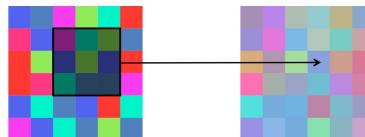
What types of **filtering** can we do?

Point Operation



point processing

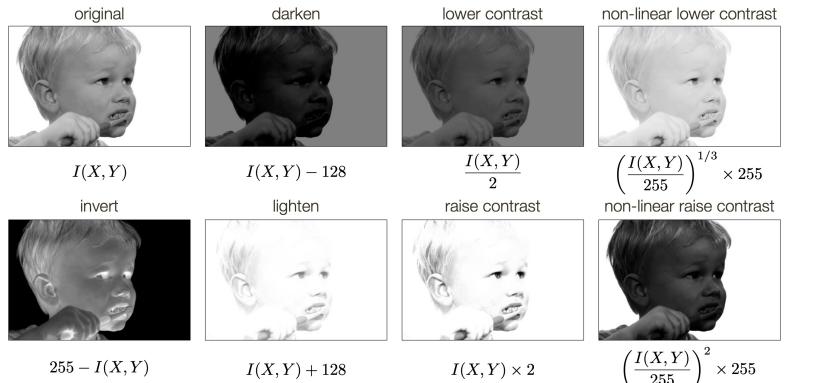
Neighborhood Operation



“filtering”

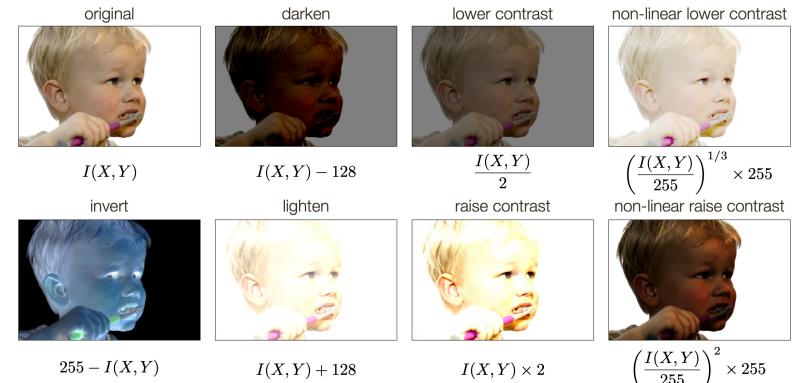
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Examples of Point Processing



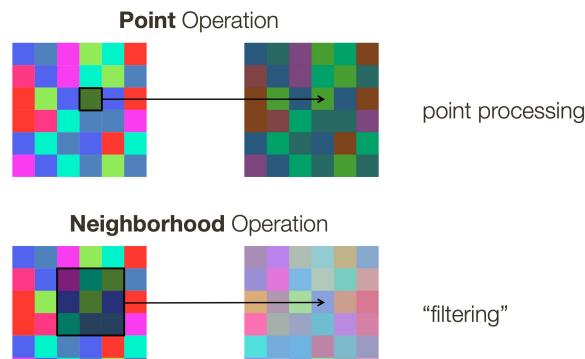
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Examples of Point Processing



Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

What types of **filtering** can we do?

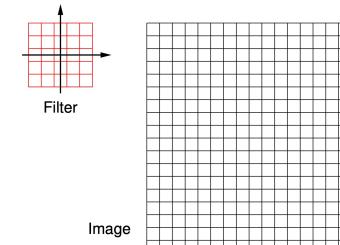


Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filters

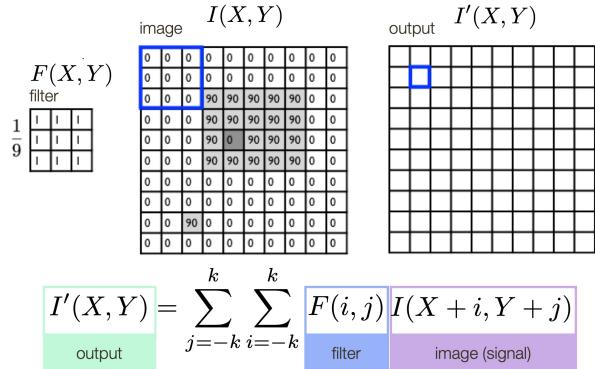
Let $I(X, Y)$ be an $n \times n$ digital image (for convenience we let width = height)

Let $F(X, Y)$ be another $m \times m$ digital image (our "**filter**" or "**kernel**")



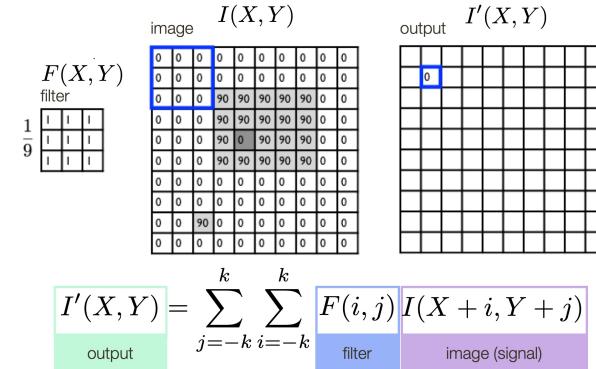
For convenience we will assume m is odd. (Here, $m = 5$)

Linear Filter Example



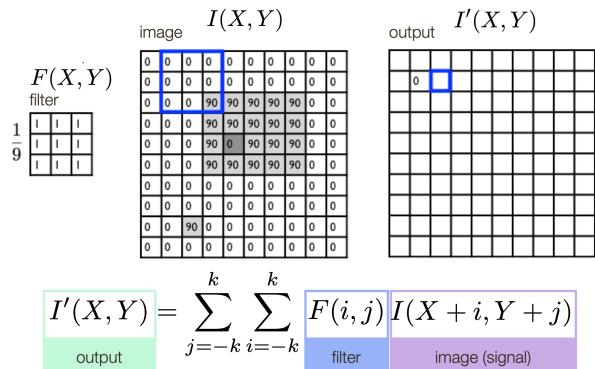
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



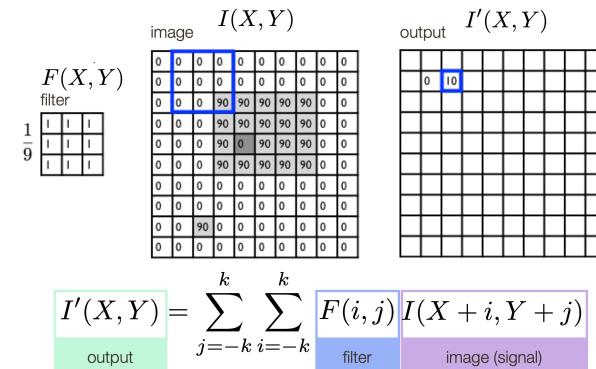
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



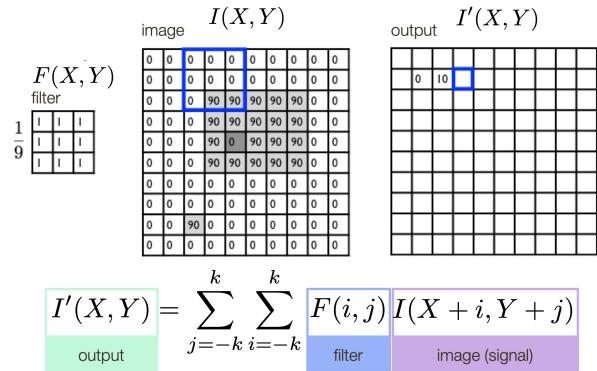
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



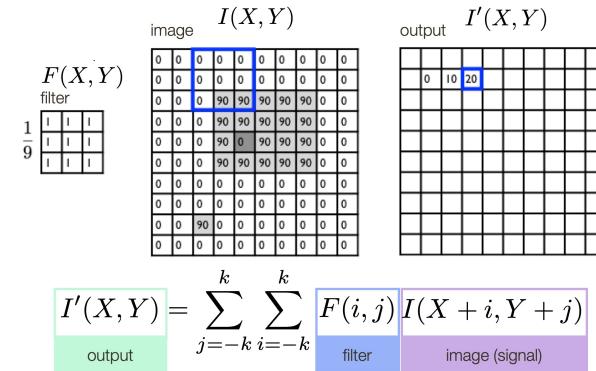
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



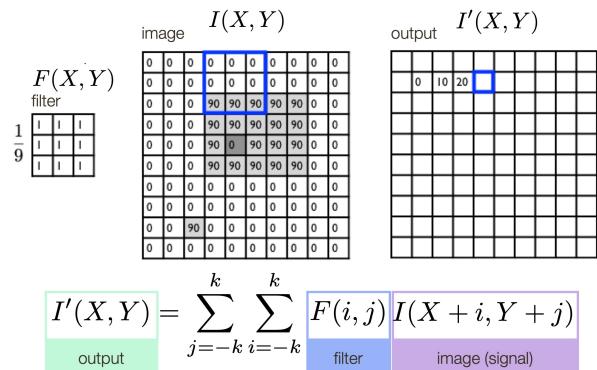
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

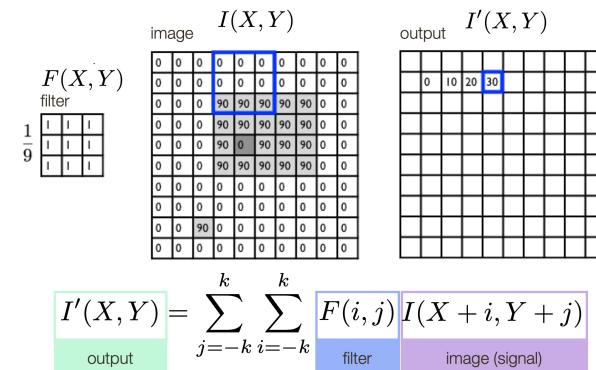
Linear Filter Example



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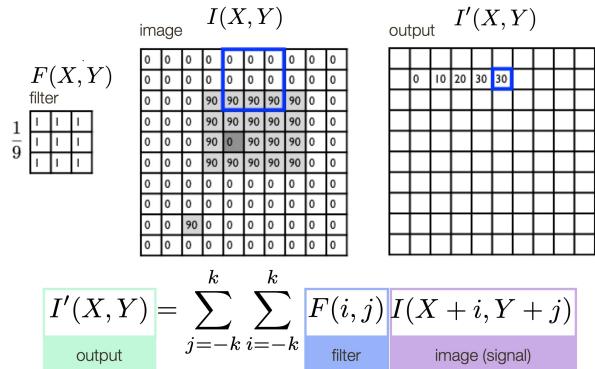
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



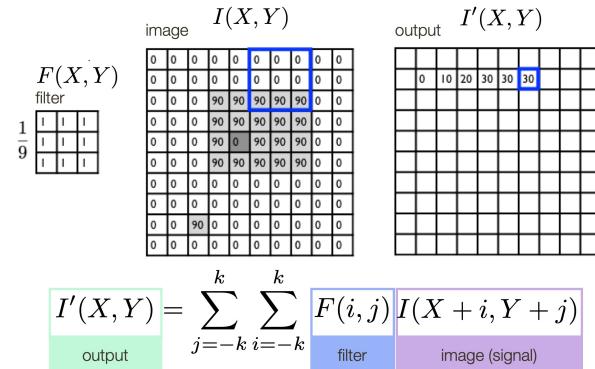
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



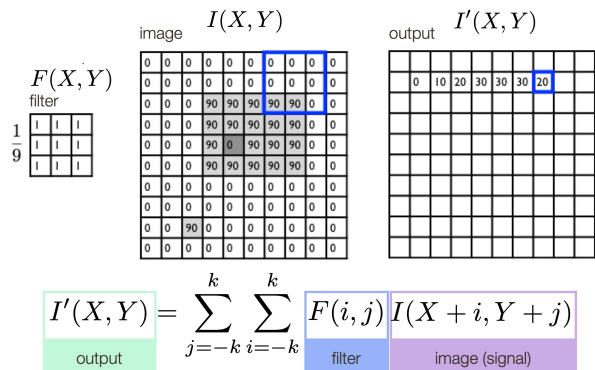
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



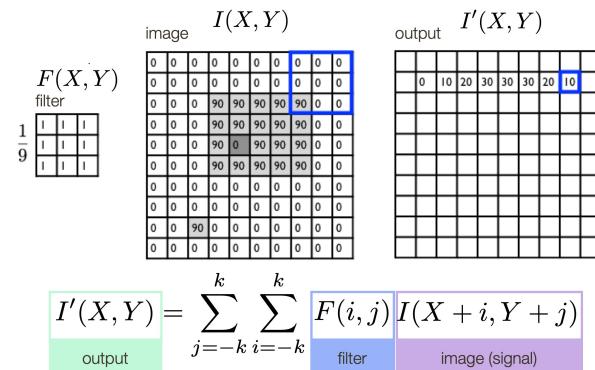
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



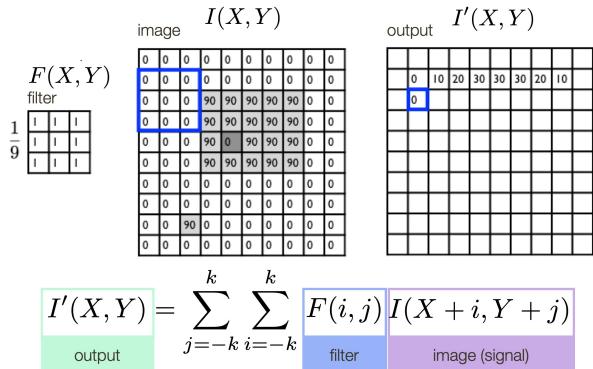
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



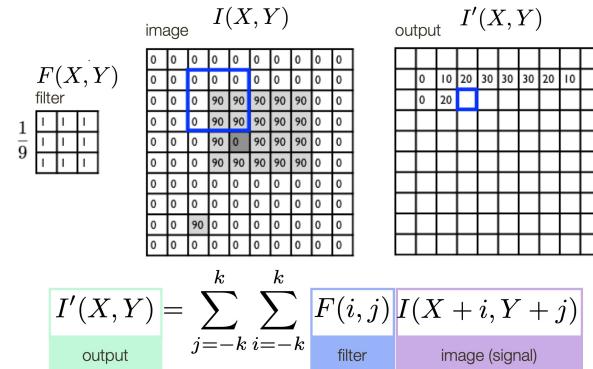
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



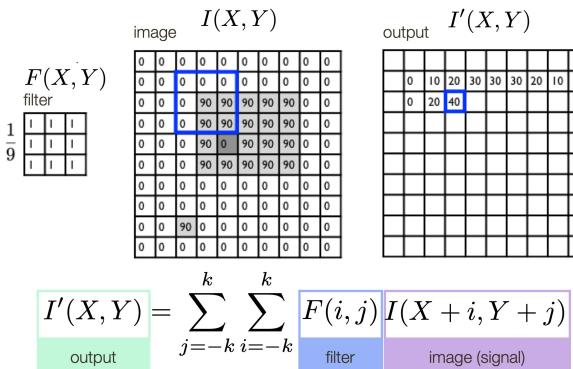
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter **Example**



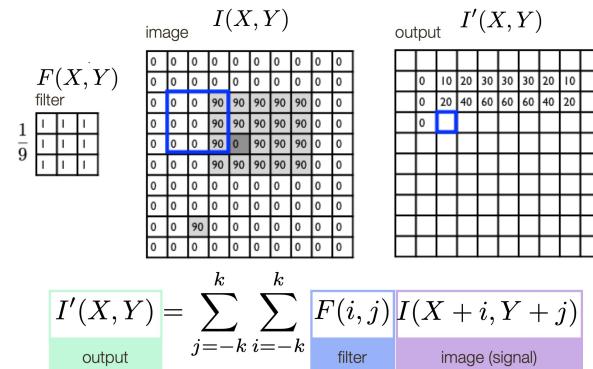
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



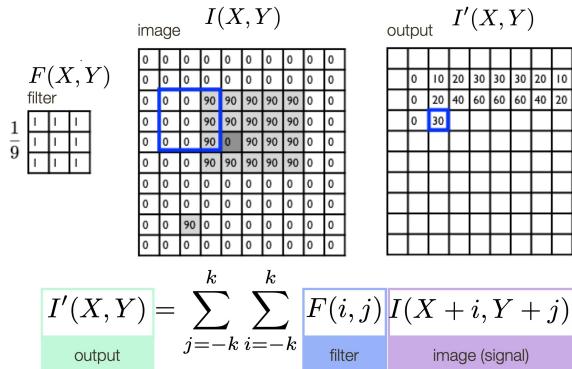
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



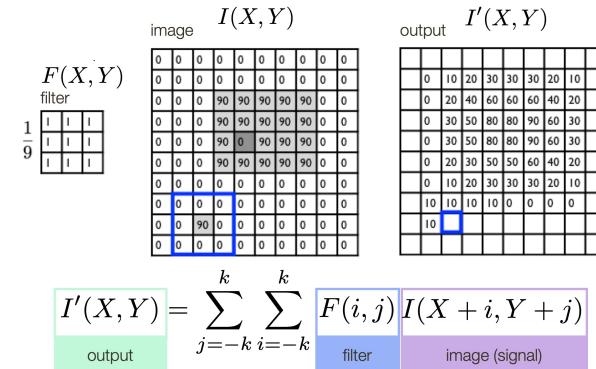
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



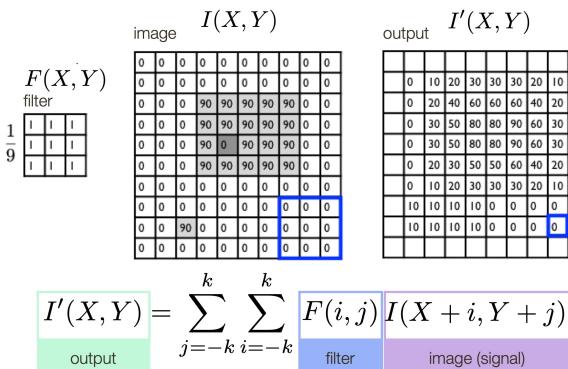
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



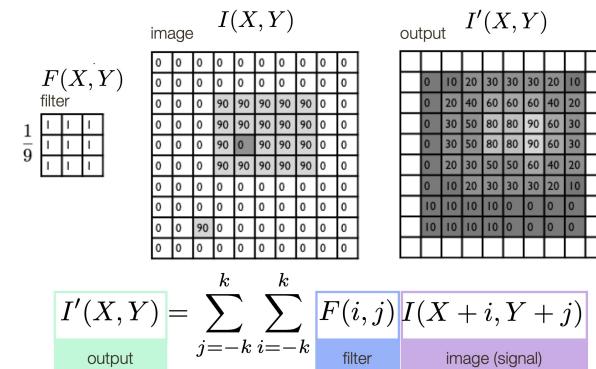
Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filter Example



Slide Credit: Ioannis (Yannis) Gkioulekas (CMU)

Linear Filters: Correlation vs. Convolution

Definition: **Correlation**

$$I'(X, Y) = \sum_{j=-k}^k \sum_{i=-k}^k F(i, j)I(X + i, Y + j)$$

a b c	1 2 3
d e f	4 5 6
g h i	7 8 9

Filter

1 2 3
4 5 6
7 8 9

Image

Output

$$= 1a + 2b + 3c + 4d + 5e + 6f + 7g + 8h + 9i$$

Linear Filters: Correlation vs. Convolution

Definition: **Correlation**

$$I'(X, Y) = \sum_{j=-k}^k \sum_{i=-k}^k F(i, j)I(X + i, Y + j)$$

Definition: **Convolution**

$$I'(X, Y) = \sum_{j=-k}^k \sum_{i=-k}^k F(i, j)I(X - i, Y - j)$$

a b c
d e f
g h i

Filter

1 2 3
4 5 6
7 8 9

Image

Output

$$= 9a + 8b + 7c + 6d + 5e + 4f + 3g + 2h + 1i$$

Linear Filters: Correlation vs. Convolution

Definition: **Correlation**

$$I'(X, Y) = \sum_{j=-k}^k \sum_{i=-k}^k F(i, j)I(X + i, Y + j)$$

Definition: **Convolution**

$$I'(X, Y) = \sum_{j=-k}^k \sum_{i=-k}^k F(i, j)I(X - i, Y - j)$$

Filter
(rotated by 180)

! Ȣ Ȧ
Ȣ Ȧ Ȫ
Ȧ Ȫ ȫ

a b c
d e f
g h i

Filter

1 2 3
4 5 6
7 8 9

Image

Output

$$= 9a + 8b + 7c + 6d + 5e + 4f + 3g + 2h + 1i$$