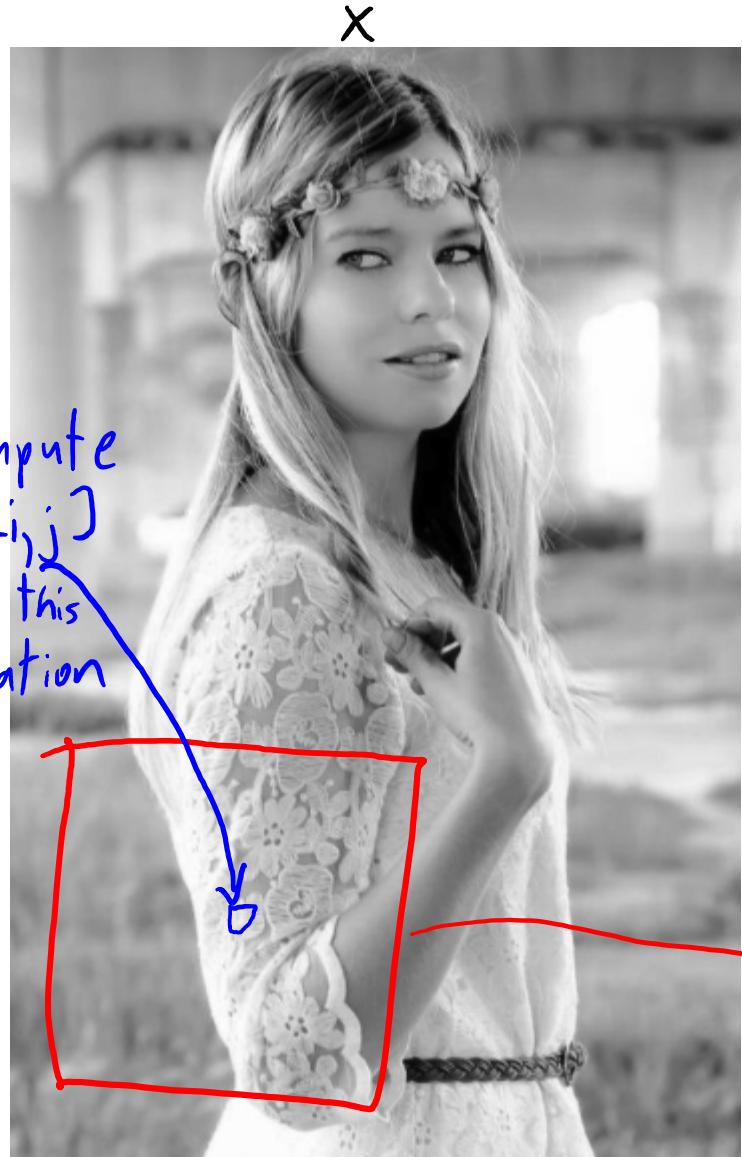


# CPSC 340: Machine Learning and Data Mining

Convolutional Neural Networks

BONUS SLIDES  
(convolutions)

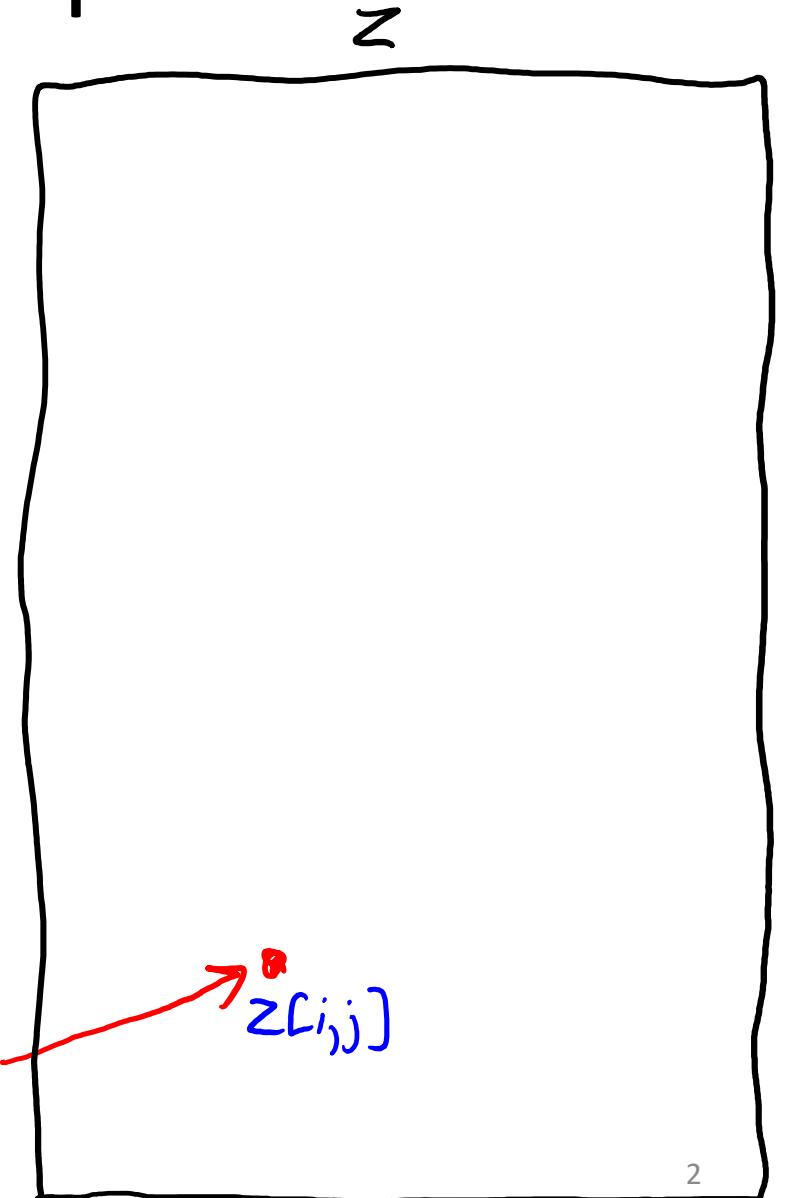
# Image Convolution Examples



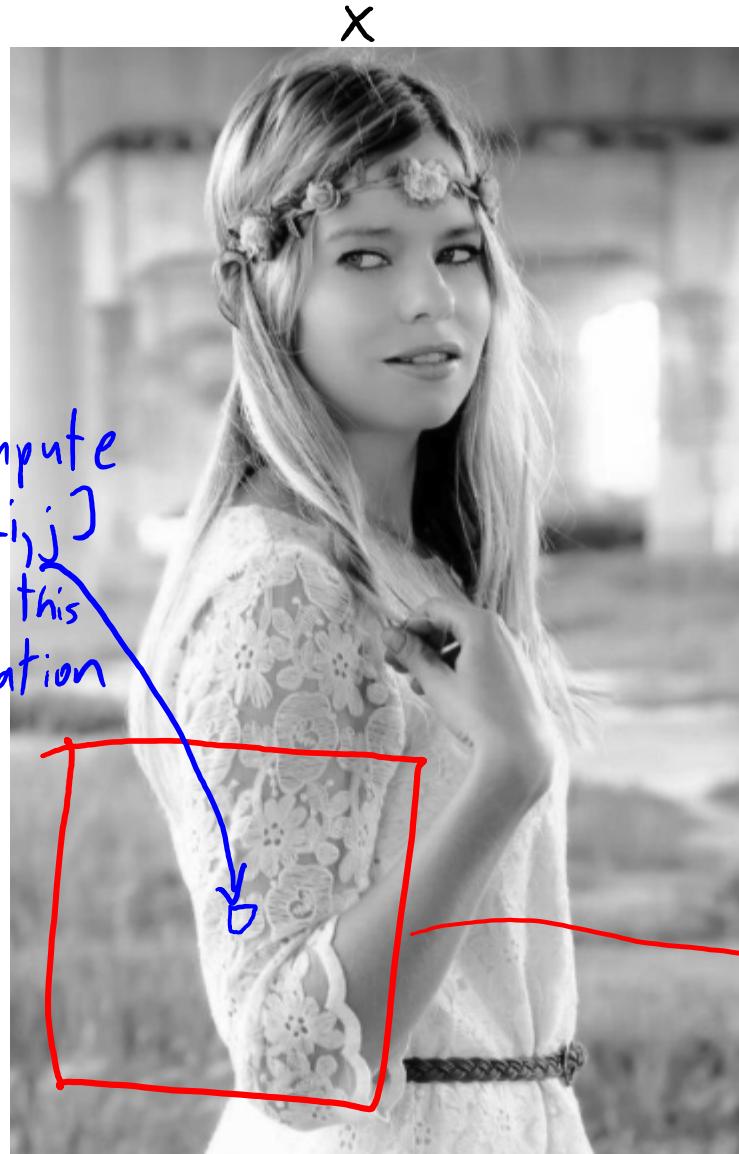
$$X \star W = Z$$

A diagram illustrating the convolution operation. An input image  $X$  is multiplied element-wise by a weight matrix  $W$  to produce the output  $Z$ . The weight matrix  $W$  is shown as a solid black rectangle with a central white dot, representing a 3x3 kernel. The result of the multiplication is shown as a white rectangle with a black border, representing the output feature map  $Z$ .

multiply element-wise  
and add up result to get



# Image Convolution Examples



Identity convolution:  
(zeroes with a '1' at  $w_{0,0}$ )

$$w \quad *

A 3x3 black square representing the kernel  $w$ . It has a single white dot in the center, representing  $w_{0,0}$ .$$

multiply element-wise  
and add up result to get



# Image Convolution Examples



Translation Convolution:

$$* \quad \quad =$$
A diagram illustrating translation convolution. On the left, there is a small black square representing an input image patch. In the top-left corner of this patch, there is a small red circle. To the right of this patch is an equals sign (=). To the right of the equals sign is a larger black square representing an output image patch. A green arrow points from the top-left corner of this output patch to the handwritten text "Oc".

Boundary: "zero"



# Image Convolution Examples



Translation Convolution:

$$\begin{matrix} * \\ \text{---} \\ \ast \end{matrix} \quad \begin{matrix} \text{---} \\ \text{---} \\ \text{---} \end{matrix} = \begin{matrix} \text{---} \\ \text{---} \\ \text{---} \end{matrix}$$

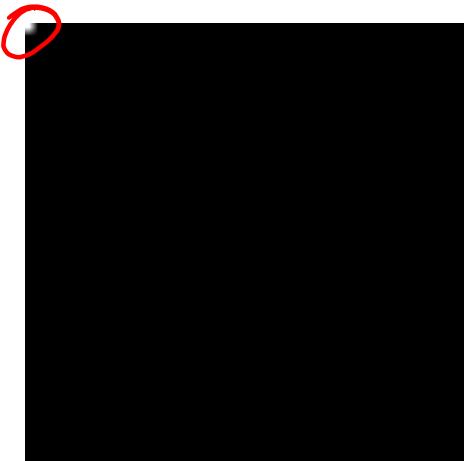
Boundary: "replicate"



# Image Convolution Examples



Translation Convolution:



Boundary: "mirror"



# Image Convolution Examples



Translation Convolution:

$$\begin{matrix} * \\ \text{ } \\ \text{ } \end{matrix} \quad \begin{matrix} \text{ } \\ \text{ } \\ \text{ } \end{matrix} = \quad \begin{matrix} \text{ } \\ \text{ } \\ \text{ } \end{matrix}$$

Boundary: "ignore"



# Image Convolution Examples



Average convolution:

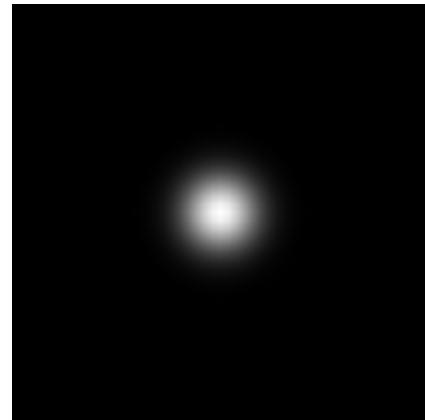
$$\ast \frac{1}{51} \begin{bmatrix} 1 & 1 & 1 & \cdots & 1 \\ 1 & 1 & 1 & \searrow & 1 \\ 1 & 1 & 1 & \cdots & 1 \\ 1 & 1 & 1 & \cdots & 1 \end{bmatrix} =$$



# Image Convolution Examples



\*



=

(smooths image)

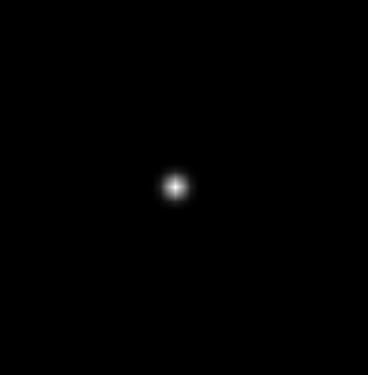


# Image Convolution Examples



Gaussian Convolution:

$\ast$       =



(smaller variance)

(smooths image)

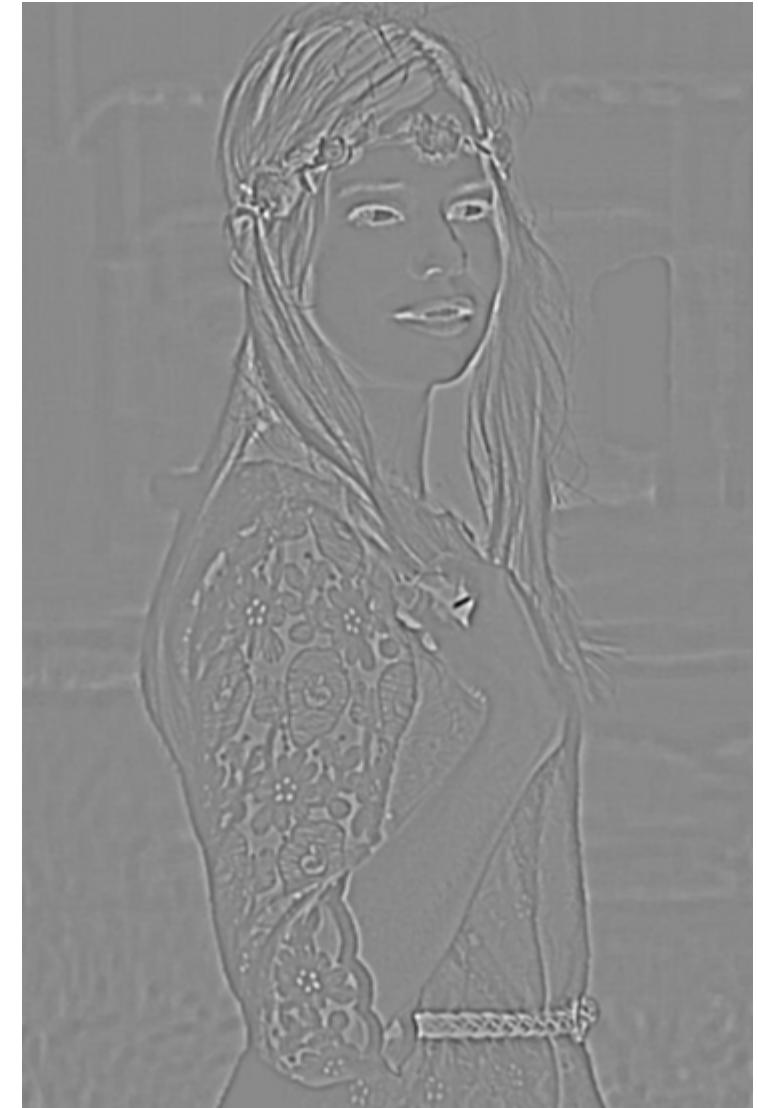


# Image Convolution Examples



Laplacian of Gaussian

$$\begin{matrix} * & & \\ & \bullet & \\ & & = \end{matrix}$$

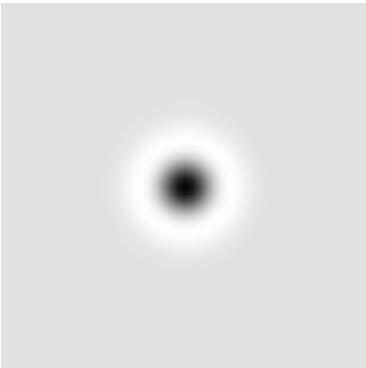


# Image Convolution Examples



Laplacian of Gaussian

\*



=

(larger variance)

Similar preprocessing may be  
done in basal ganglia and LGN.



# Image Convolution Examples



"Emboss" filter:

$$\ast \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix} =$$

Many Photoshop effects  
are just convolutions.

<http://setosa.io/ev/image-kernels>

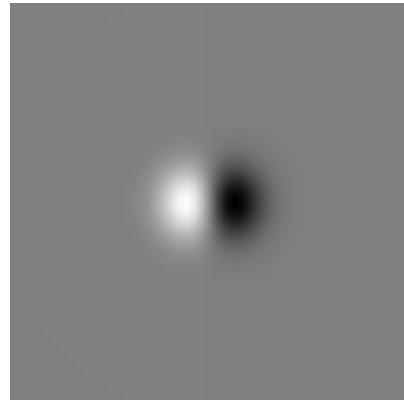


# Image Convolution Examples

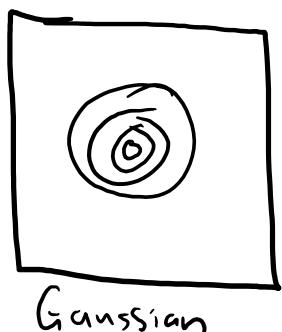


Gabor filter  
(Gaussian multiplied by  
Sine or cosine)

\*



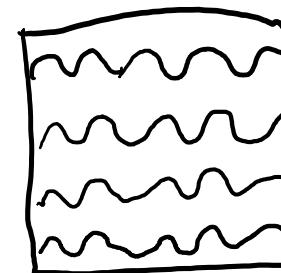
=



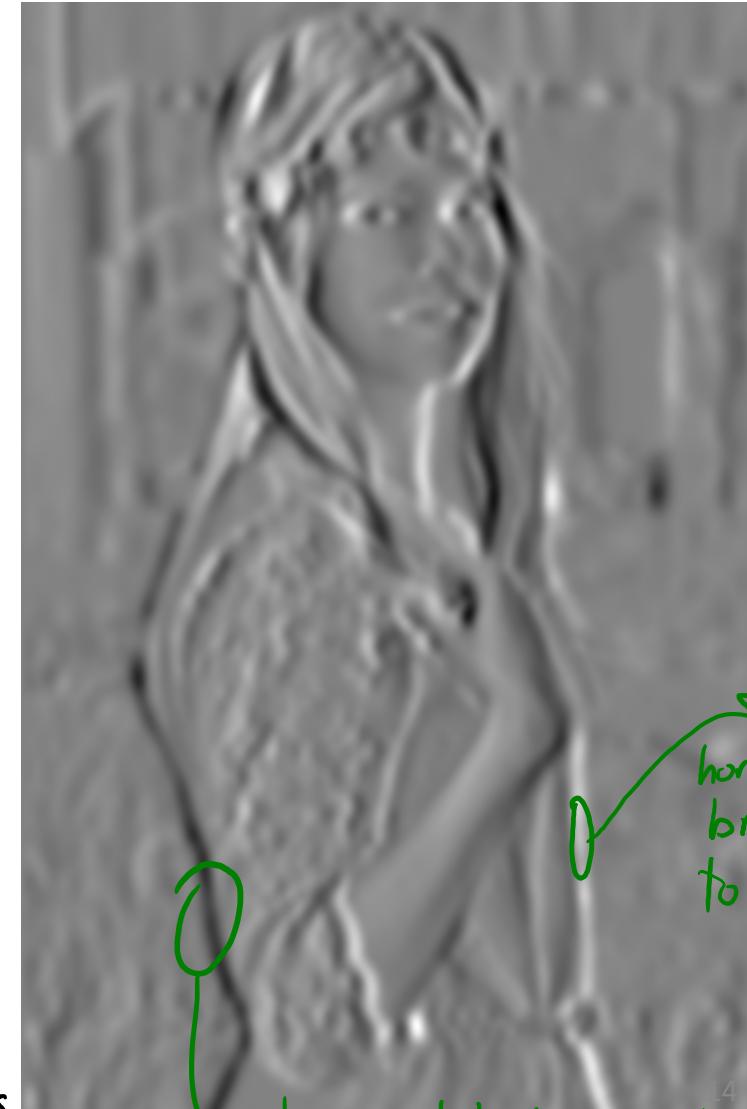
Gaussian

||

\*



Parallel Sine functions

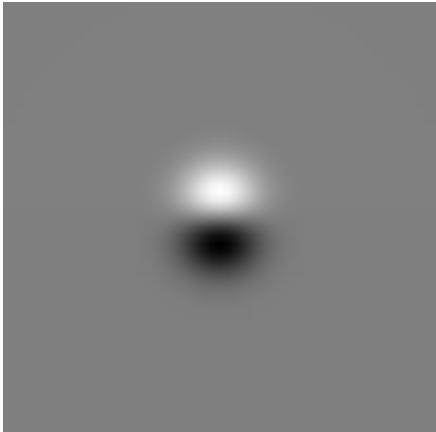


# Image Convolution Examples



Gabor filter  
(Gaussian multiplied by  
Sine or cosine)

\*



=

Different orientations of  
the sine/cosine let us  
detect changes with different  
 orientations.

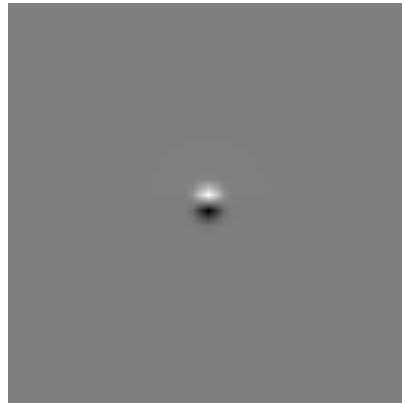


# Image Convolution Examples



Gabor filter  
(Gaussian multiplied by  
Sine or cosine)

\*



=

(smaller variance)

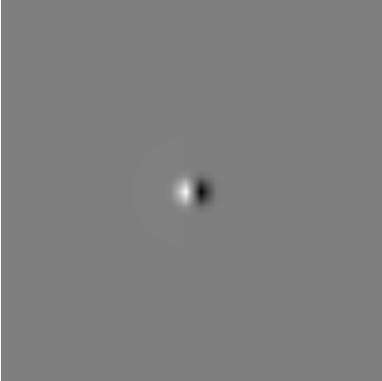


# Image Convolution Examples



Gabor filter  
(Gaussian multiplied by  
Sine or cosine)

\*



=

(smaller variance)

Vertical orientation

- Can obtain other orientations by rotating.

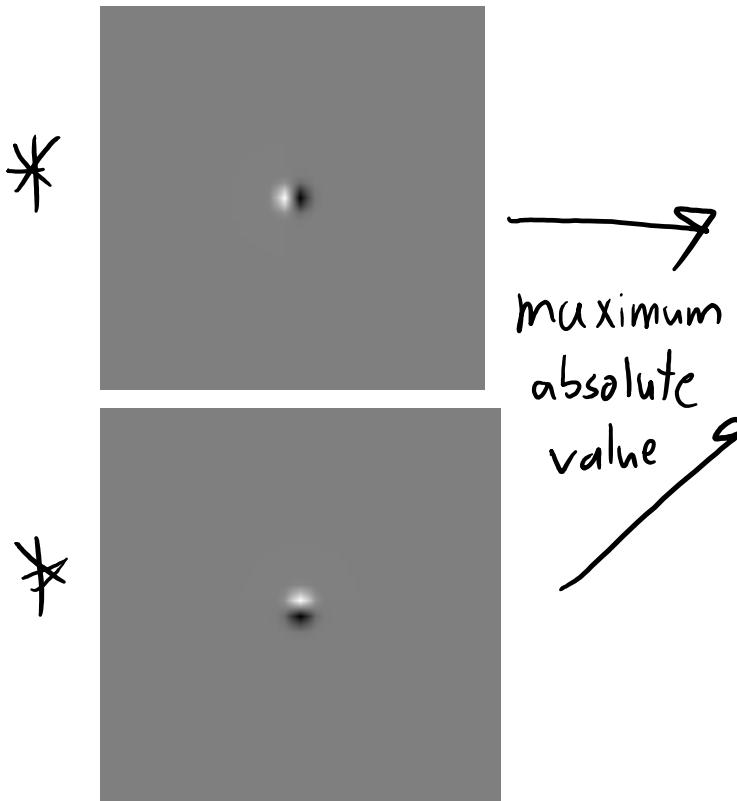
- May be similar to effect of V1 "simple cells."



# Image Convolution Examples



Max absolute value  
between horizontal and  
vertical Gabor:



"Horizontal/vertical edge detector"

# 3D Convolution



Represent  
as RGB



Can apply 3D  
convolutions

# 3D Convolution



Gaussian filter



# 3D Convolution



Gaussian filter  
(higher variance on  
green channel)



# 3D Convolution



Sharpen the blue channel.



# 3D Convolution



Gabor filter on  
each channel.

