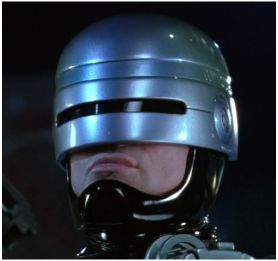
CS325 Artificial Intelligence
Ch. 24, Computer Vision I – Object Recognition

Cengiz Günay, Emory Univ.



Spring 2013

Computer Vision

- Done with games, except homework :)

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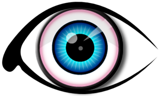
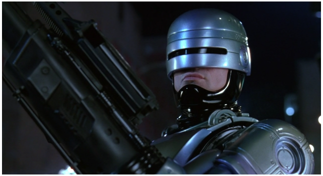


- **Vision** is one of our main perceptions
- **Computer vision** is what robots use to understand their surrounding



Computer Vision

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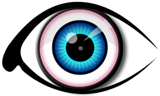

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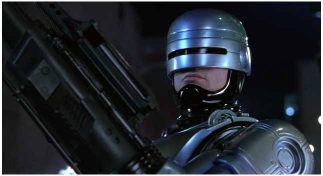
3 lectures:

1. Object recognition (today)
2. 3D reconstruction
3. Motion analysis



Entry/Exit Surveys

Exit survey: Advanced Planning

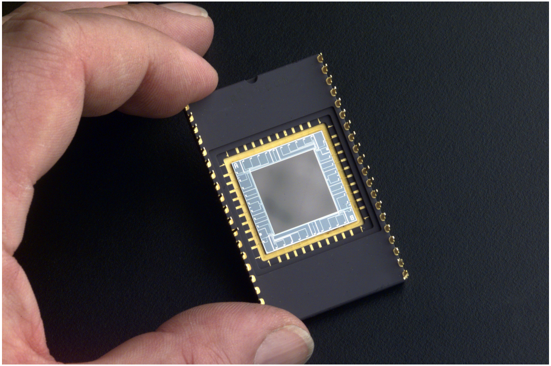
- Why isn't classical planning schema adequate for resource planning?
- What is the advantage gained in abstract plans by having *surely-reachable* versus *potentially-reachable* states?

Entry survey: Computer Vision I – Image Processing (0.25 points)

- List three specific tasks where computer vision would be desirable.
- What do you think are the major hurdles in computer vision?

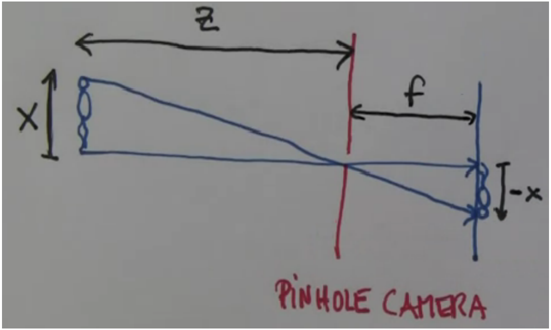
How Machines See: Cameras

A charge-coupled device (CCD) photo sensor array:



Focal Optics for Determining Distance and Size

See the videos, I'll summarize:



$$\frac{X}{Z} = \frac{x}{f}$$

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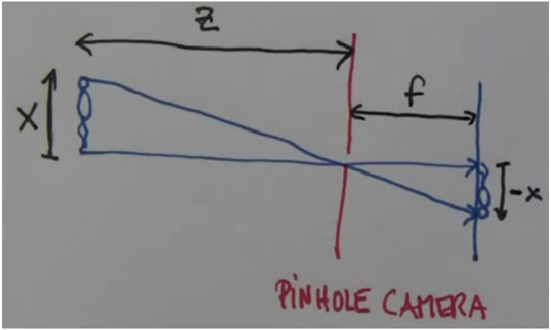

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What can we can figure out from this?

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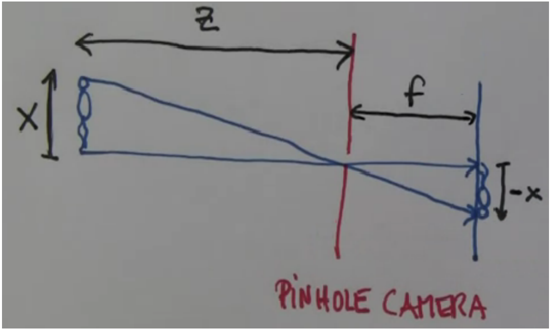

$$\frac{X}{Z} = \frac{x}{f}$$

What can we can figure out from this?

- Object's distance (Z) & height (X) based on projection height (x) and focal distance (f)

We All See a Perspective Projection

Vanishing points from parallel lines:

We All See a Perspective Projection

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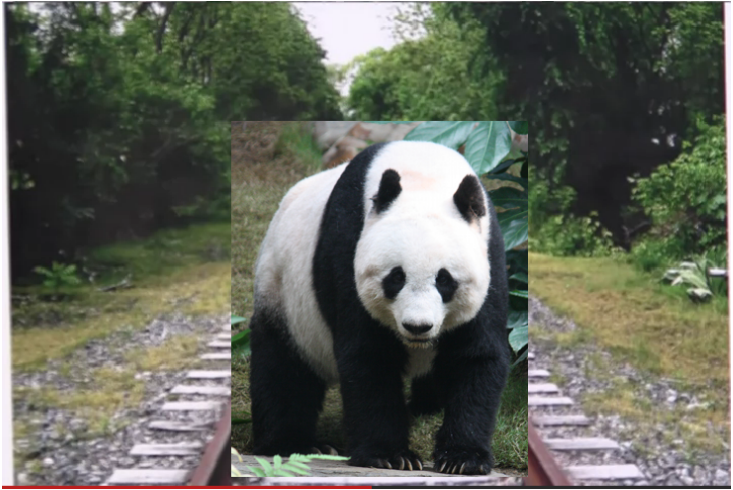

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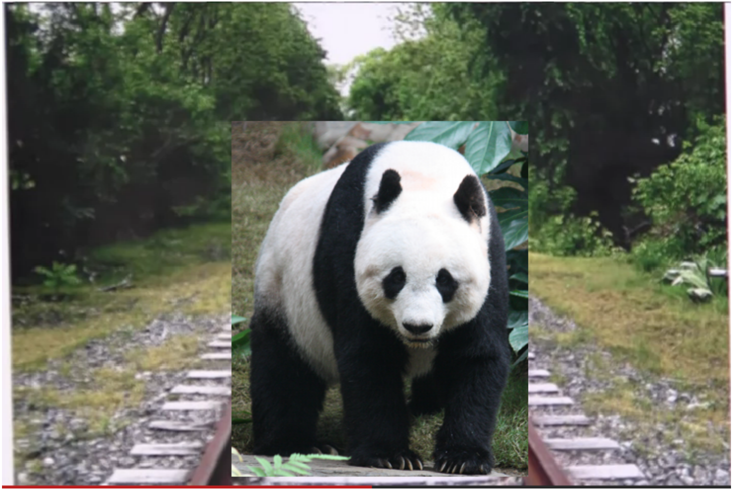

- Giant panda, or just close?

Object Recognition: How Hard Can It Be?

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Problems?

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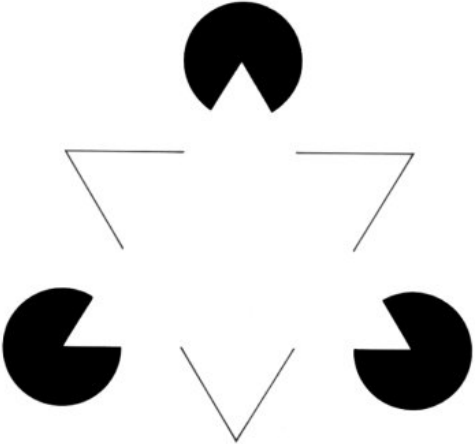
Problems?

- Rotation, scale, illumination, occlusion, viewpoint, deformation

Not Hard for Us



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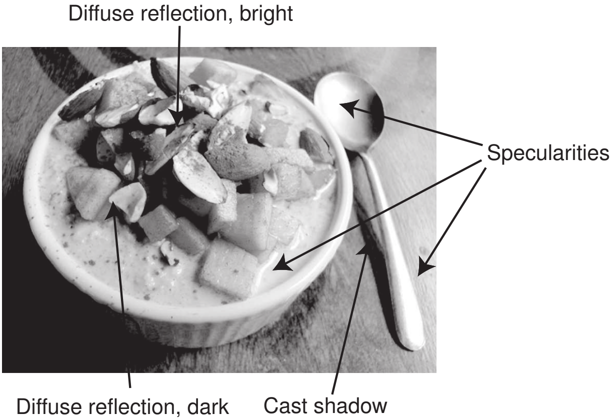

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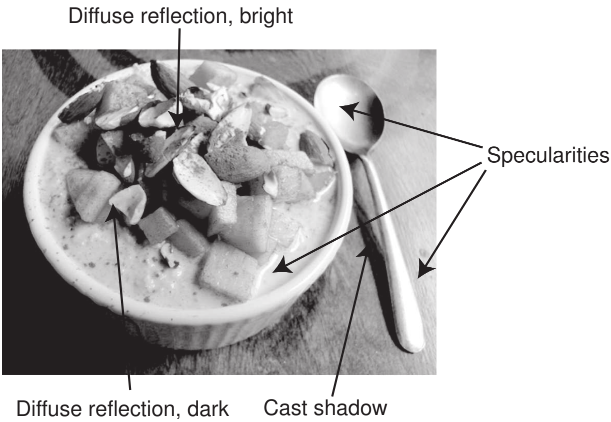
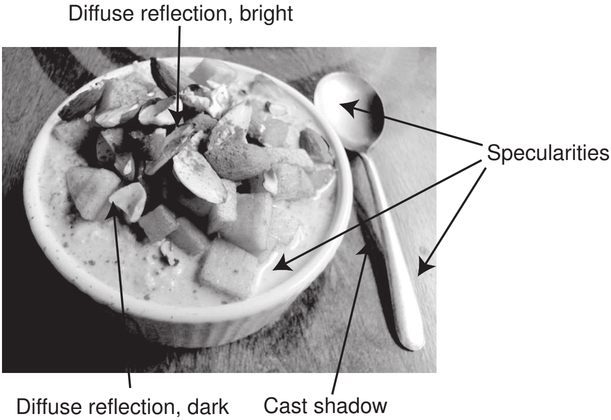


How does our brain do it?

Not Hard for Us



How does our brain do it? Will have examples later.

Invariance is Crucial for Computer Vision

Must recognize objects **invariant** of their:

- Rotation, scale, illumination, occlusion, viewpoint, deformation

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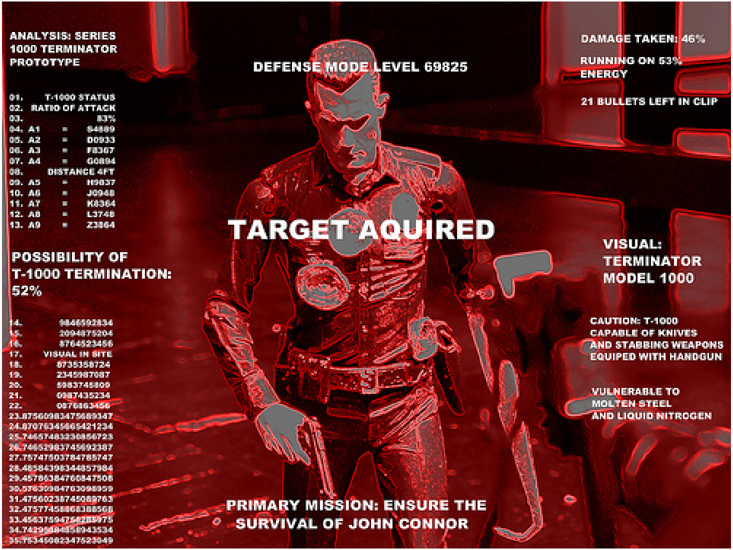
Let's start by simplifying:

1. Greyscale (monochrome) images
2. Pixels can have values: $0 \ldots 255$

Even Terminator Has Monochrome Vision



Extracting Features: Edge Detection

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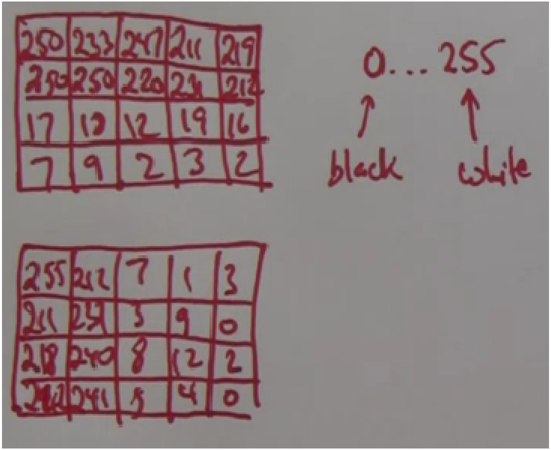
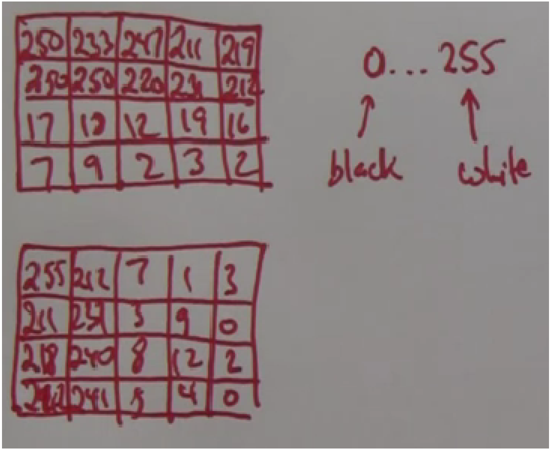
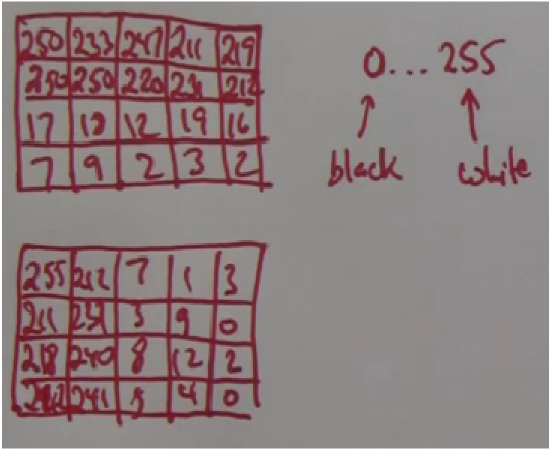


Extracting Features: Edge Detection



How to detect the vertical edge?

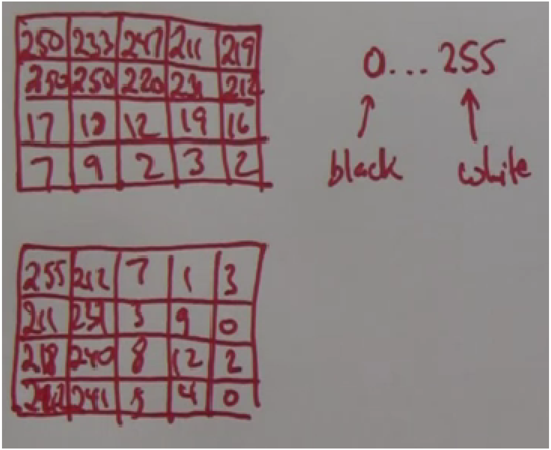
Extracting Features: Edge Detection



How to detect the vertical edge?

1. Spatial derivative?

Extracting Features: Edge Detection

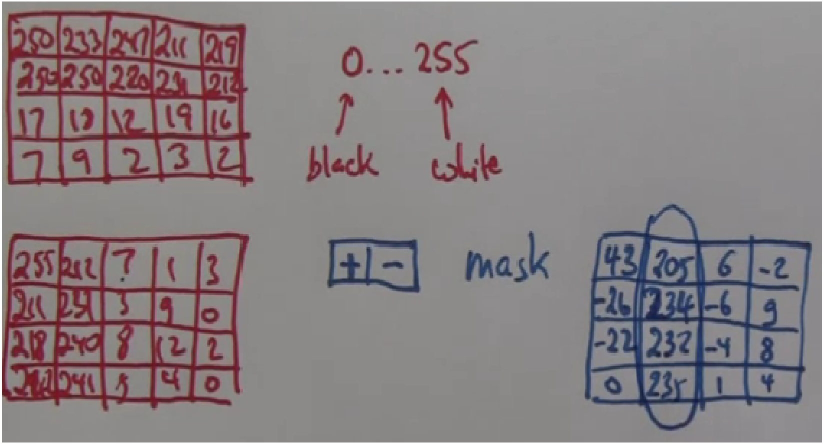


How to detect the vertical edge?

1. Spatial derivative?
2. Filter with mask:

$+1$	-1

Extracting Features: Edge Detection



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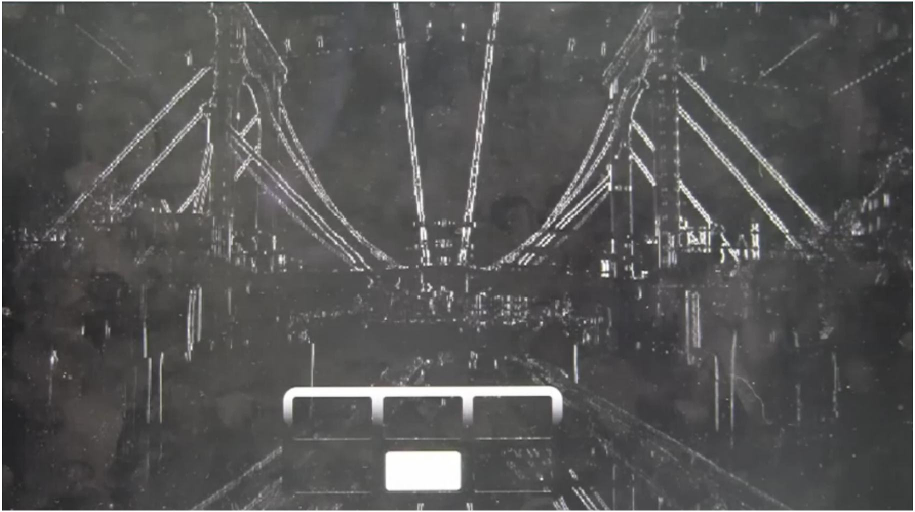
Extracting Features: Edge Detection



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Edge Detection: Linear Filter

What we did is called **convolution**:

$$I \otimes g = I'$$

$$\otimes \quad = $$

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For each pixel, we multiply by **mask** and sum:

$$I'(x,y) = \sum_{u,v} I(x-u, y-v)\, g(u,v)$$

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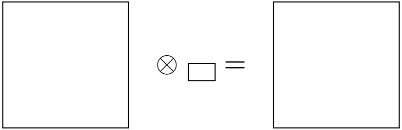

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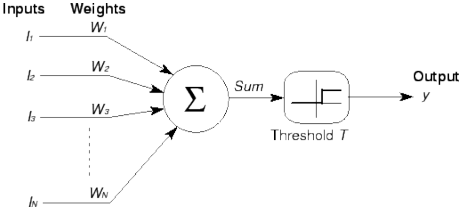
Perceptron?



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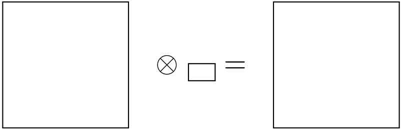

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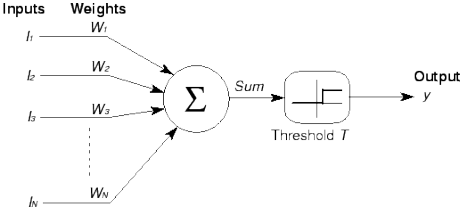
Perceptron?

- What are the weights?



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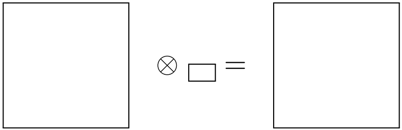

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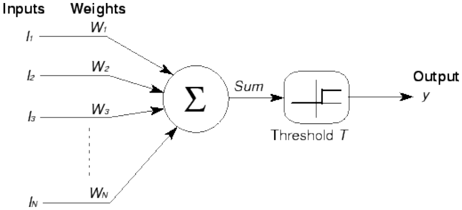

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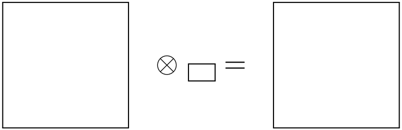

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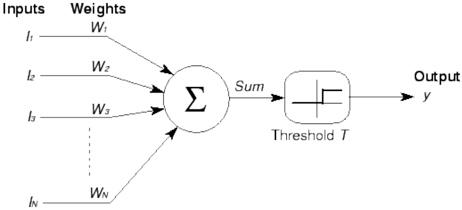
- What's the advantage?



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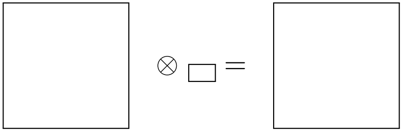

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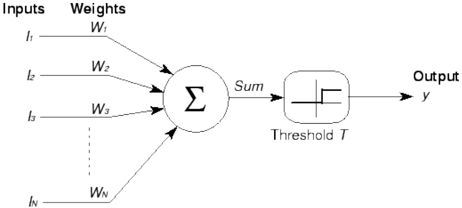
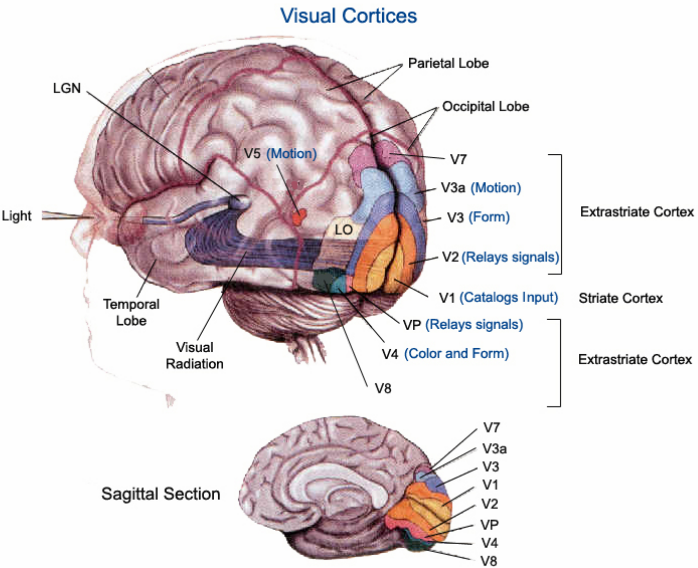
Perceptron?

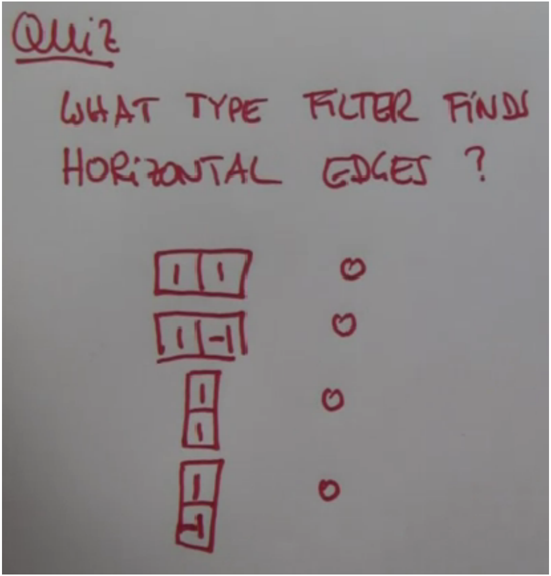
- What are the weights?
  The mask, g.
- What's the advantage?
  Works in parallel!



Neurons Can Do It Faster?



Detect Only Vertical Edges?



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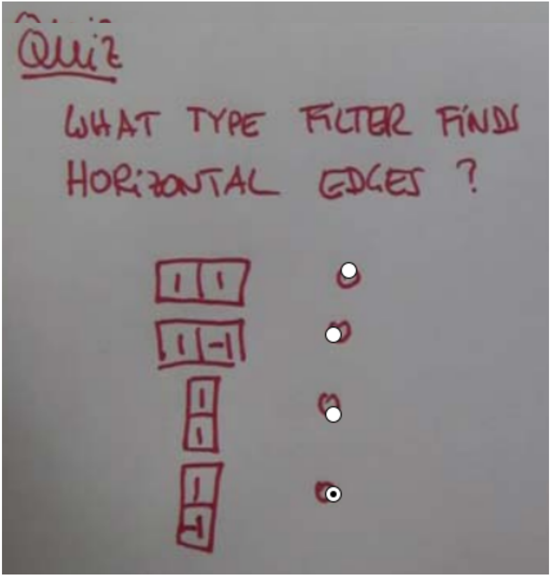
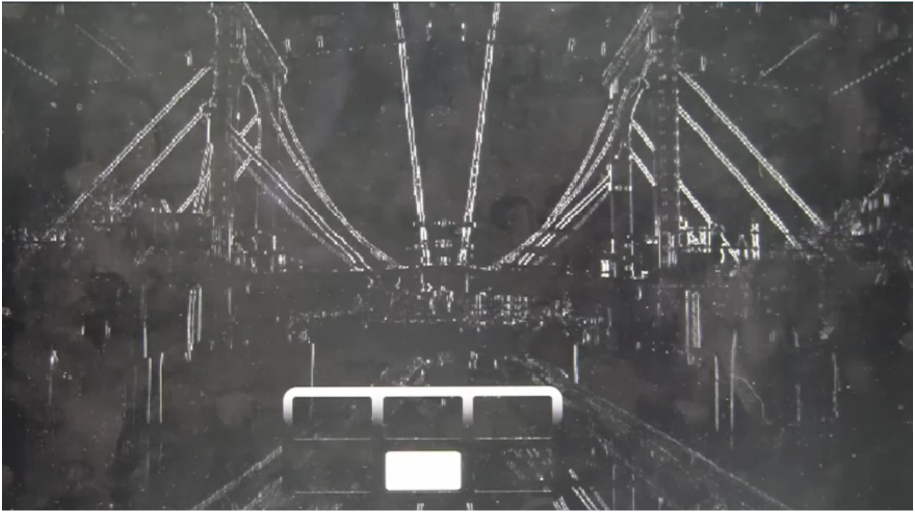


Horizontal and Vertical Gradients

Original:

Horizontal and Vertical Gradients

Vertical gradient:



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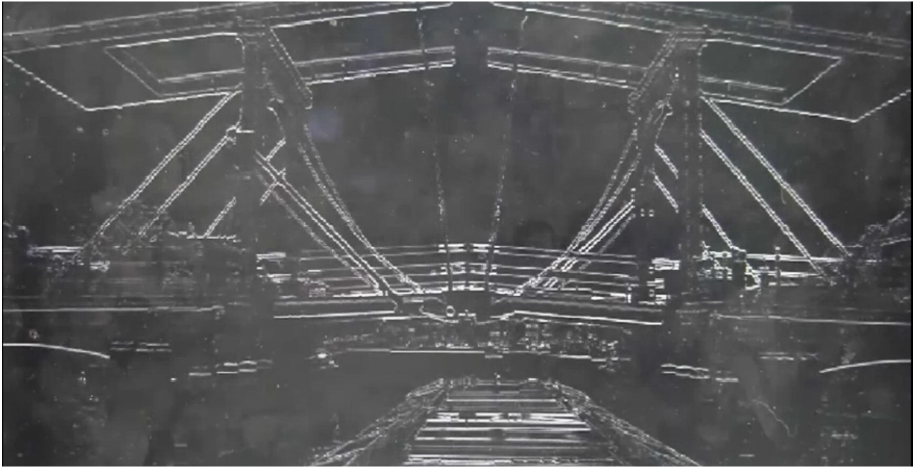

Combining Gradients

Horizontal mask gives vertical gradient (I_x) and vice versa:

$$I_x = I \otimes \boxed{\begin{array}{cc} -1 & +1 \end{array}}$$

$$I_y = I \otimes \boxed{\begin{array}{c} -1 \\ +1 \end{array}}$$

Combining Gradients

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How to combine them?

Combining Gradients

Horizontal mask gives vertical gradient (I_x) and vice versa:

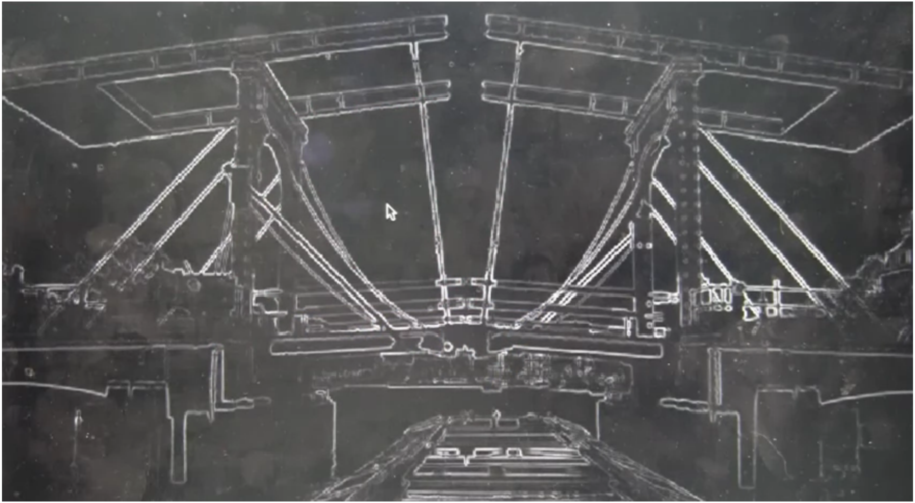
$$
\begin{aligned}
I_x &= I \otimes \boxed{\begin{matrix} -1 & +1 \end{matrix}} \\
I_y &= I \otimes \boxed{\begin{matrix} -1 \\ +1 \end{matrix}}
\end{aligned}
$$

How to combine them?

$$E = \sqrt{I_x^2 + I_y^2}$$

Horizontal and Vertical Gradients

Combined gradients:



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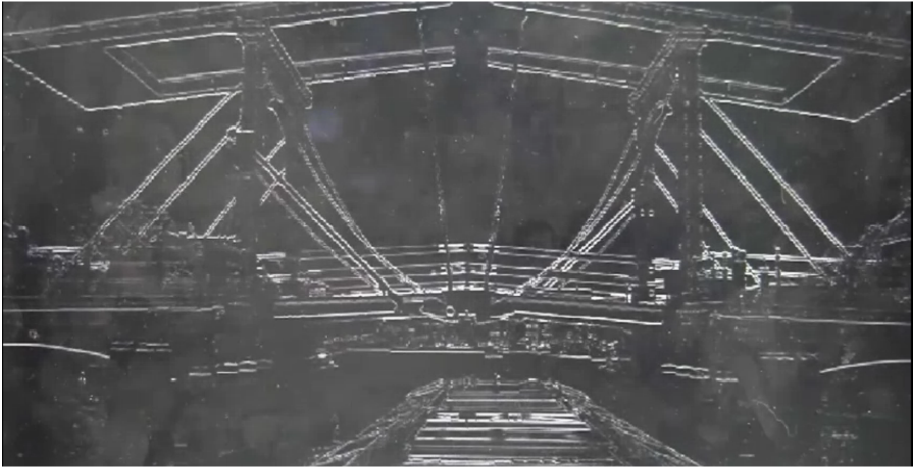

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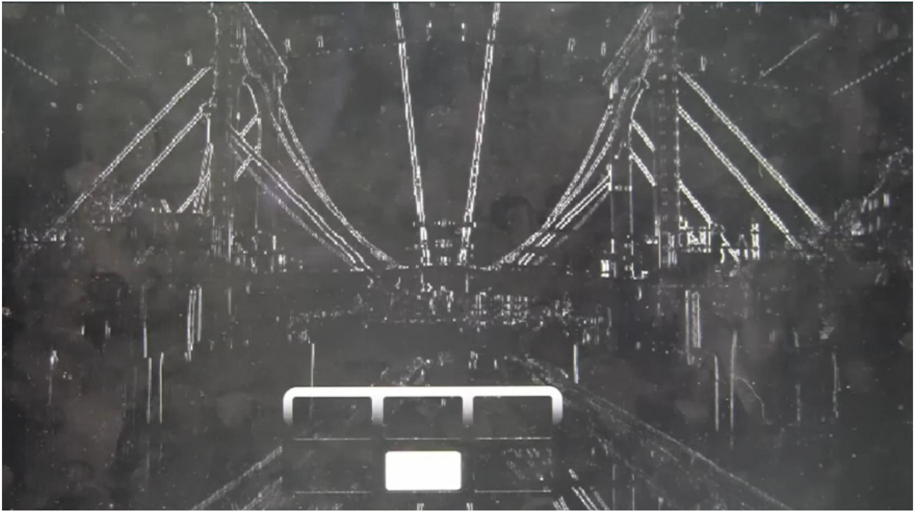

Canny Edge Detector is Uncanny!

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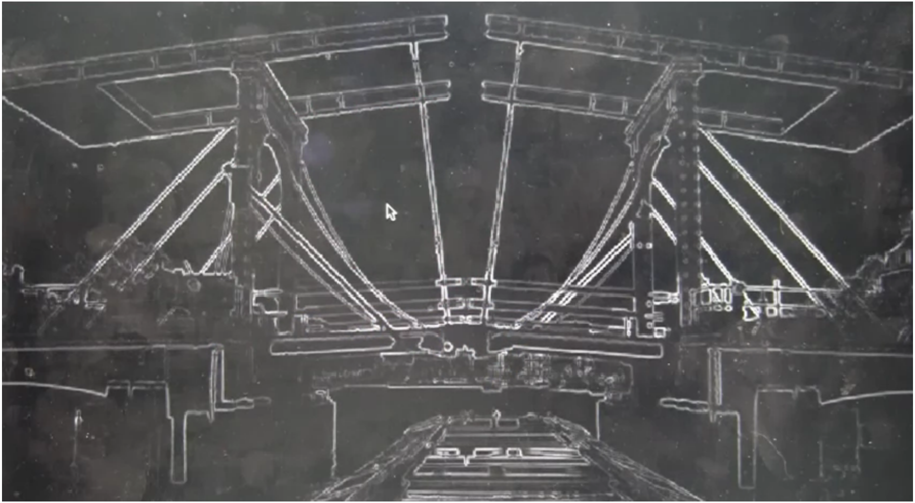
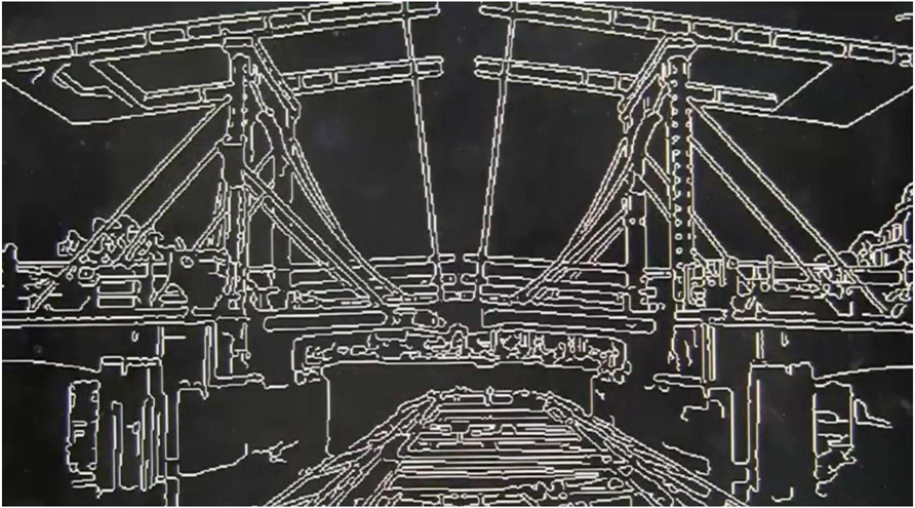
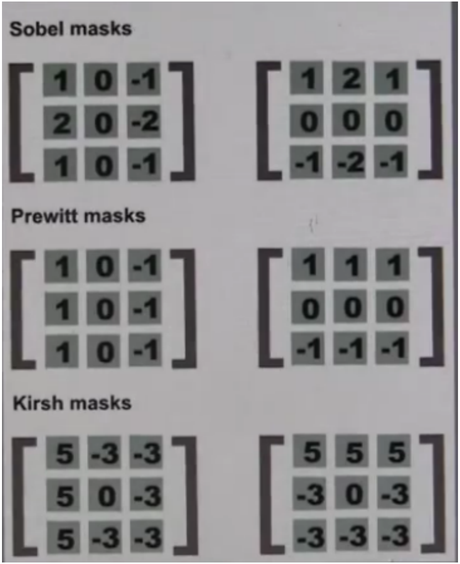


Canny Edge Detector is Uncanny!

Canny edge detector (by John Canny):



Other Edge Detection Masks



Sobel masks

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

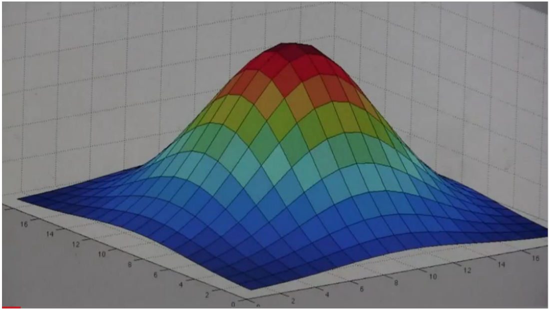
Prewitt masks

$$\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

Kirsh masks

$$\begin{bmatrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{bmatrix} \qquad \begin{bmatrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix}$$

A Gaussian Mask?



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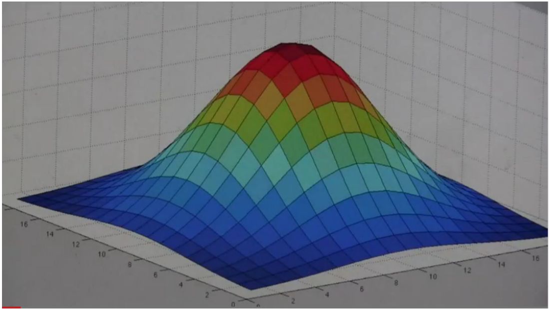
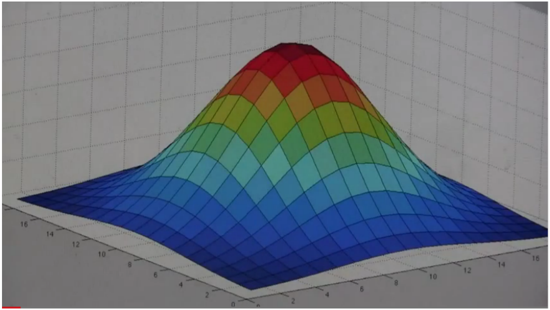


What will it do?

1. Edge filter
2. Dot filter
3. Corner
4. Blur
5. Sharpen

A Gaussian Mask?



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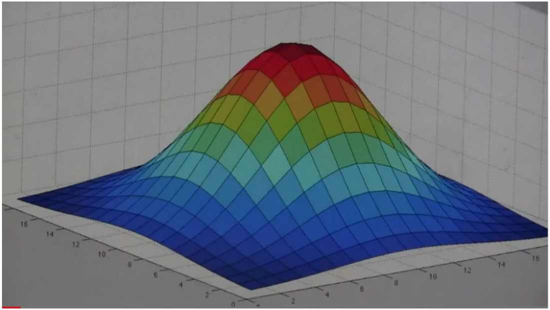
What's the Point of Blurring Images?

A Gaussian Mask?



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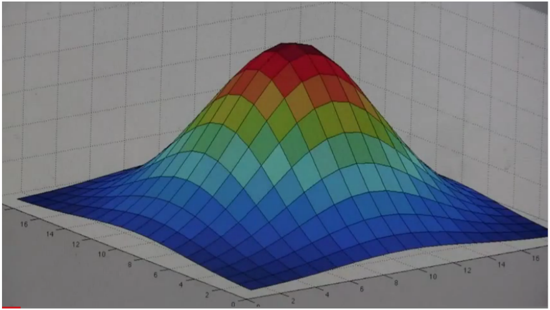
What's the Point of Blurring Images?

1. Downsampling

A Gaussian Mask?



What will it do?

1. Edge filter
2. Dot filter
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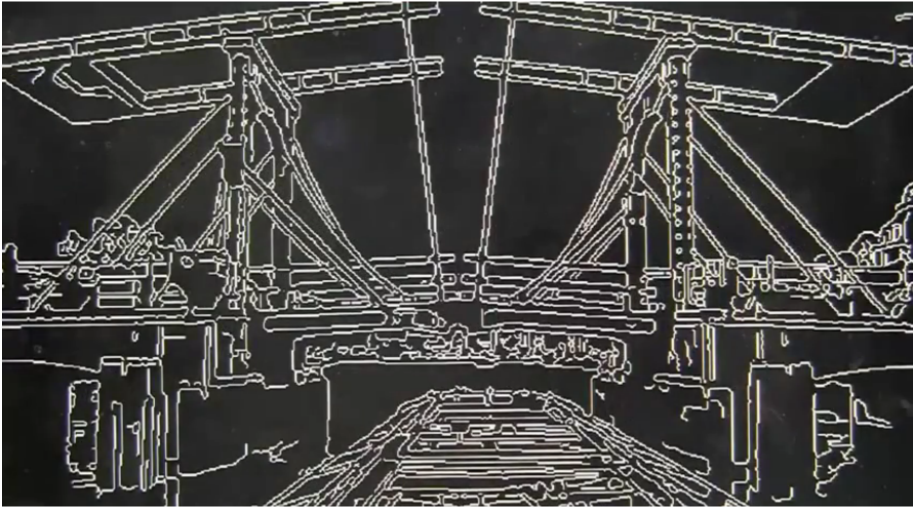
4. Blur
5. Sharpen

What's the Point of Blurring Images?

1. Downsampling
2. Noise reduction

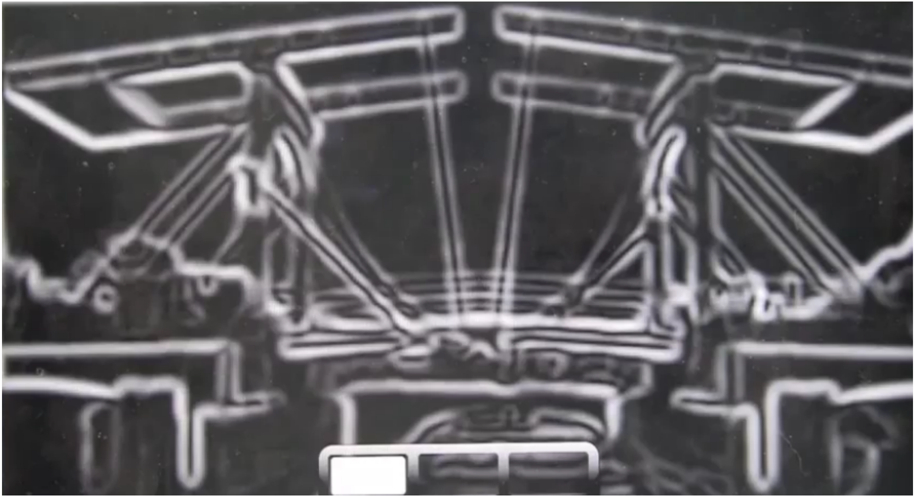
Gaussian Mask in Action

Canny filter:



Gaussian Mask in Action

Canny with Gaussian:



Tricks with Linear Filters

$$I' = I \otimes f \otimes g$$

where

- f is Gaussian mask and
- g is gradient mask.

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Does the order matter?

Tricks with Linear Filters

$$I' = I \otimes f \otimes g$$

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g is gradient mask.

Does the order matter? **No.** Linear operations are transitive.

$$= I \otimes g \otimes f$$

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Can we combine them?

Tricks with Linear Filters

$$I' = I \otimes f \otimes g$$

where

f is Gaussian mask and

g is gradient mask.

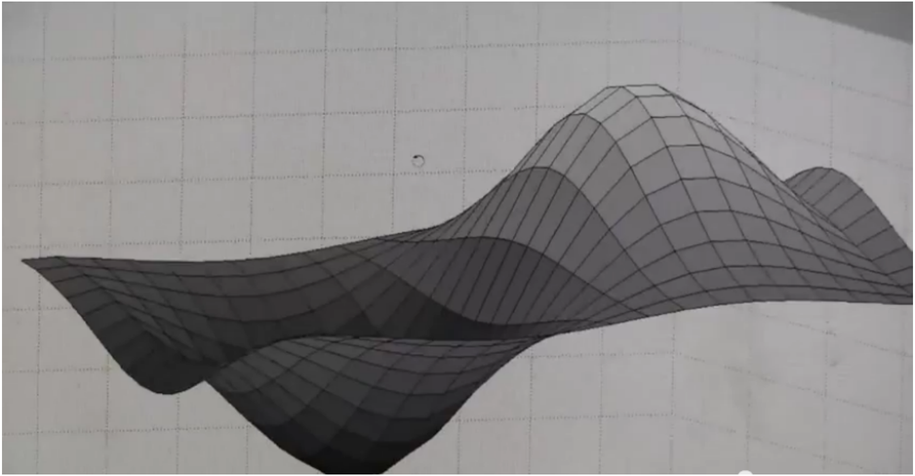
Does the order matter? **No.** Linear operations are transitive.

$$= I \otimes g \otimes f$$

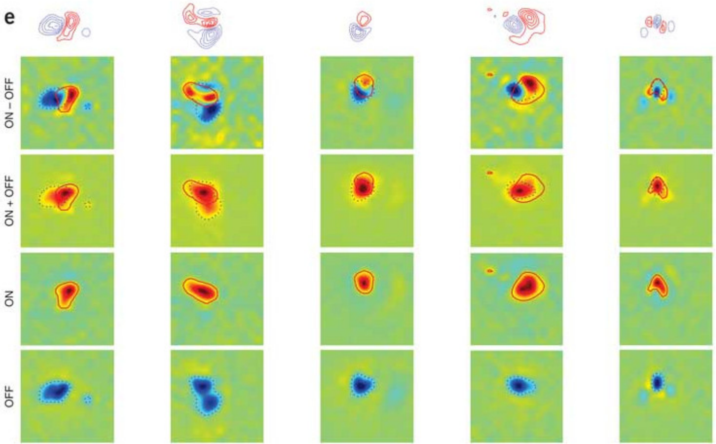
Can we combine them? **Yes.** We'll get a new linear mask/kernel.

$$= I \otimes (f \otimes g)$$

Gaussian Mask Combined with Gradient



Neurons Are Doing Exactly That!

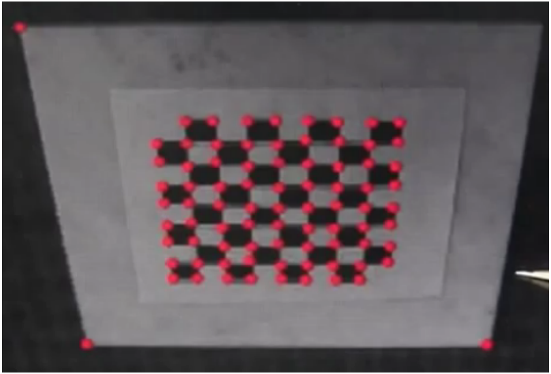


J Jin, Y Wang, HA Swadlow & JM Alonso (2011)

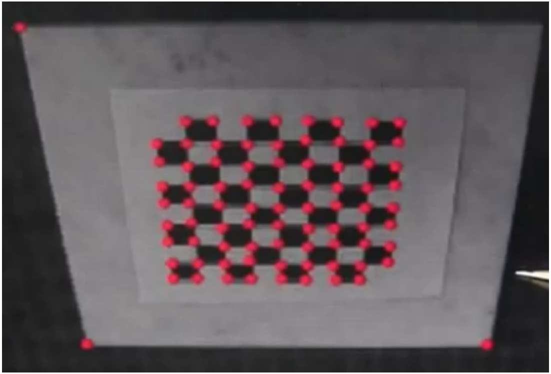
"Population receptive fields of ON and OFF thalamic inputs to an orientation column in visual cortex"

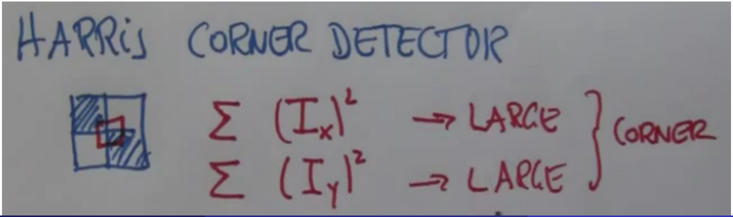
Nature Neuroscience 14(2): 232–238. doi:10.1038/nn.2729

Corner Detection

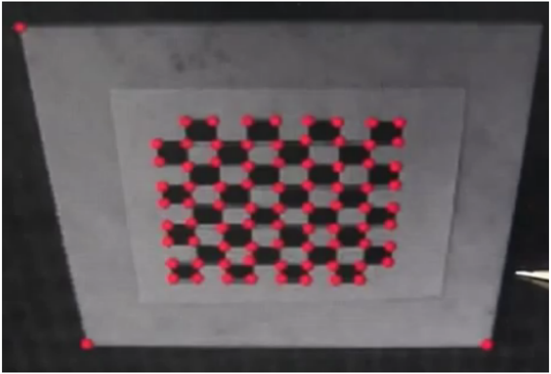


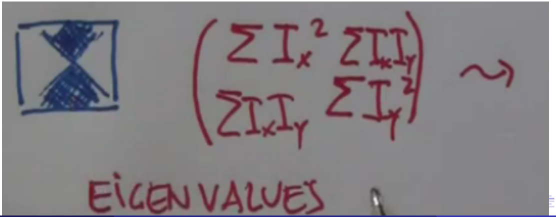
Corner Detection





Corner Detection





Modern Feature Detectors

They are:

1. Localizable
2. Unique signatures

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1. Localizable
2. Unique signatures

Two major algorithms:

1. HOG: Histogram of Oriented Gradients
2. SiFT: Scale-invariant Feature Transform

SiFT in Action