Computational Photography and Video:

Image compositing and blending

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ETH

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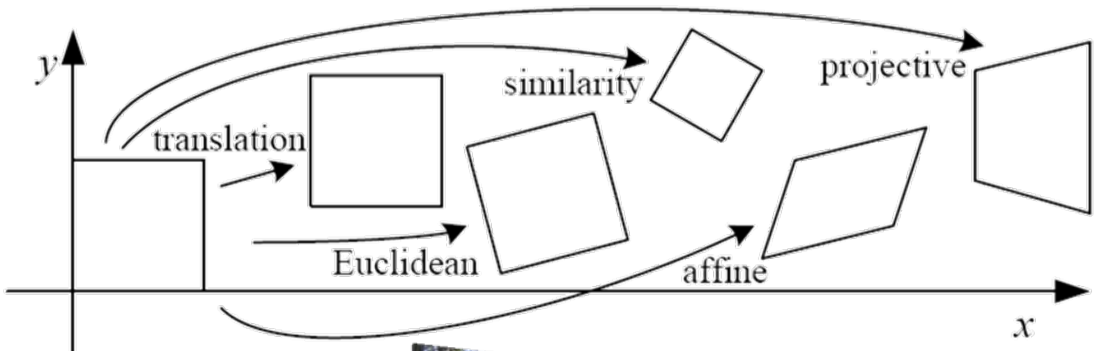
Computer Science

Today's schedule

- Last week's recap
- Image pyramids
- Graphcuts

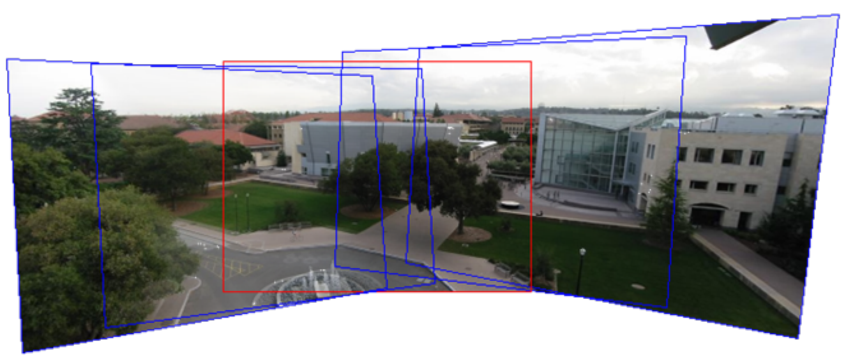
Global parametric image warping



$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\Theta & -\sin\Theta & t_x \\ \sin\Theta & \cos\Theta & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} x' \\ y' \\ w \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ w \end{bmatrix}$$

$$\begin{bmatrix} x' \\ y' \\ w' \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \begin{bmatrix} x \\ y \\ w \end{bmatrix}$$

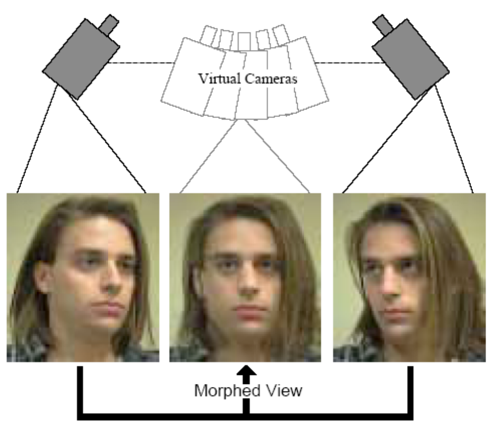


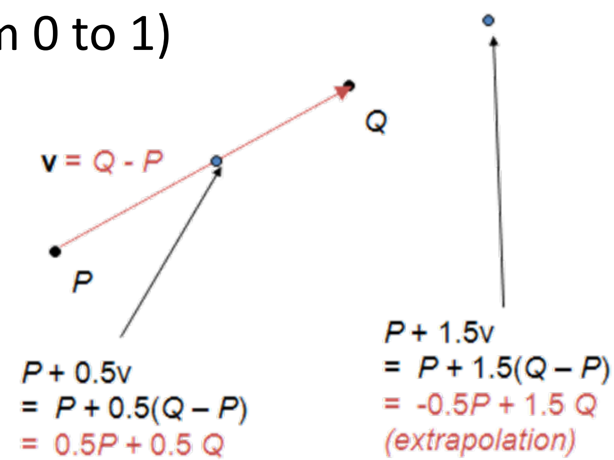
Compute homography: 2 equations/point

$$\begin{bmatrix} \mathbf{x}^\top & 0 & -x'\mathbf{x}^\top \\ 0 & \mathbf{x}^\top & -y'\mathbf{x}^\top \end{bmatrix} \begin{bmatrix} h_1^\top \\ h_2^\top \\ h_3^\top \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Morphing = Object Averaging

- Morphing:
  - Identify corresponding points and determine triangulation
  - Linearly interpolate vertex coordinates and RGB image values (vary coefficient continuously from 0 to 1)





Schedule	Computational Photography and Video	
20 Feb	Introduction to Computational Photography	
27 Feb	More on Cameras, Sensors and Color	Assignment 1: Color
5 Mar	Warping, morphing and mosaics	Assignment 2: Alignment
12 Mar	Image pyramids, Graphcuts	Assignment 3: Blending
19 Mar	Dynamic Range, HDR imaging, tone mapping	Assignment 4: HDR
26 Mar	*Easter holiday – no classes*	
2 Apr	TBD	Project proposals
9 Apr	TBD	Papers
16 Apr	TBD	Papers
23 Apr	TBD	Papers
30 Apr	TBD	Project update
7 May	TBD	Papers
14 May	TBD	Papers
21 May	TBD	Papers
28 May	TBD	Final project presentation

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Image Compositing and Blending

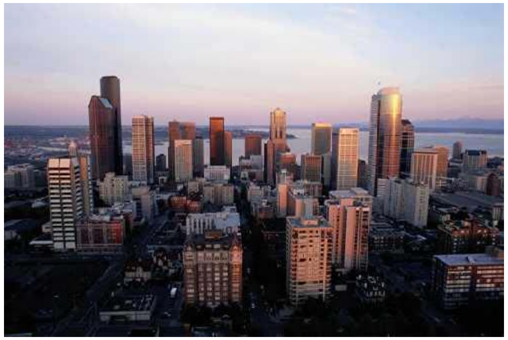
© NASA

Slides from Alexei Efros

Image Compositing

Compositing Procedure

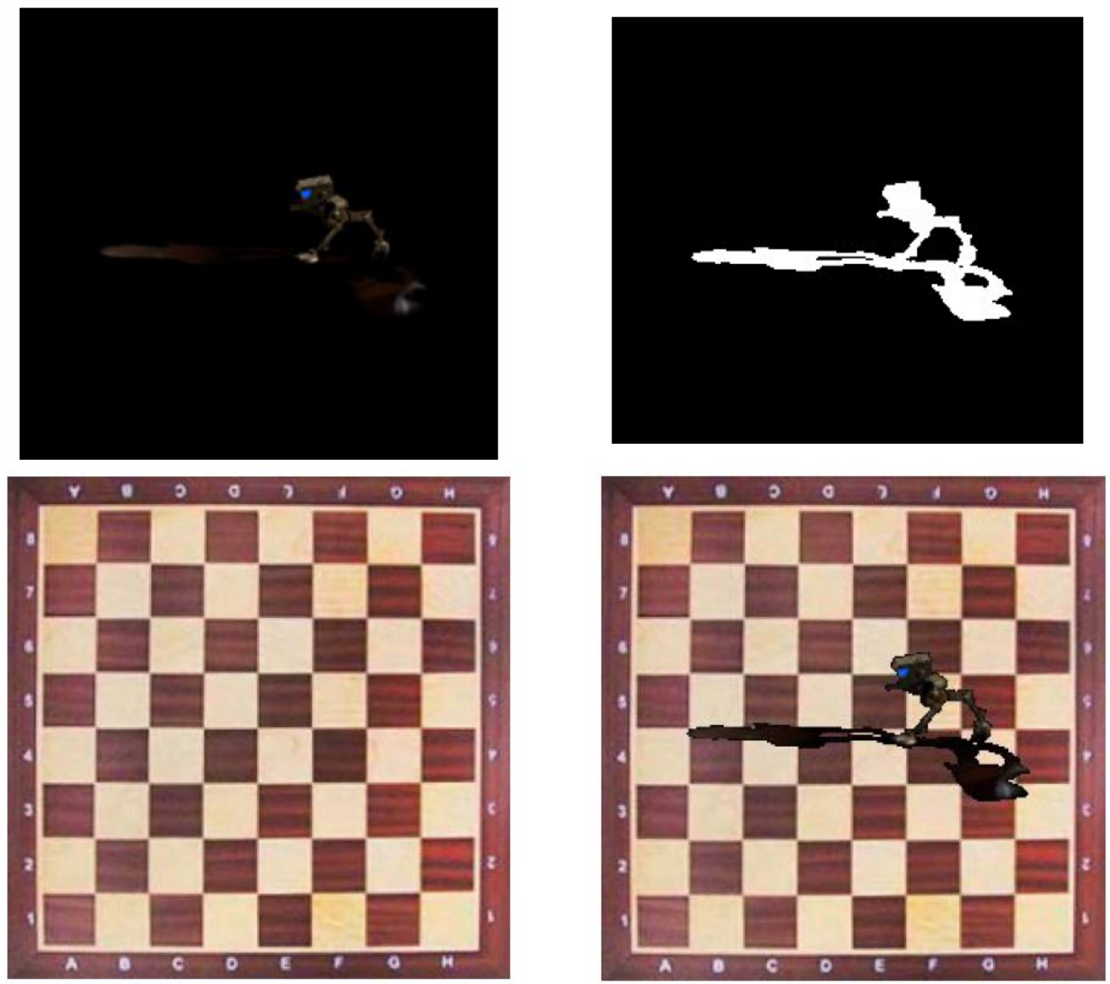
1. Extract Sprites (e.g using *Intelligent Scissors* in Photoshop)



2. Blend them into the composite (in the right order)

Composite by
David Dewey

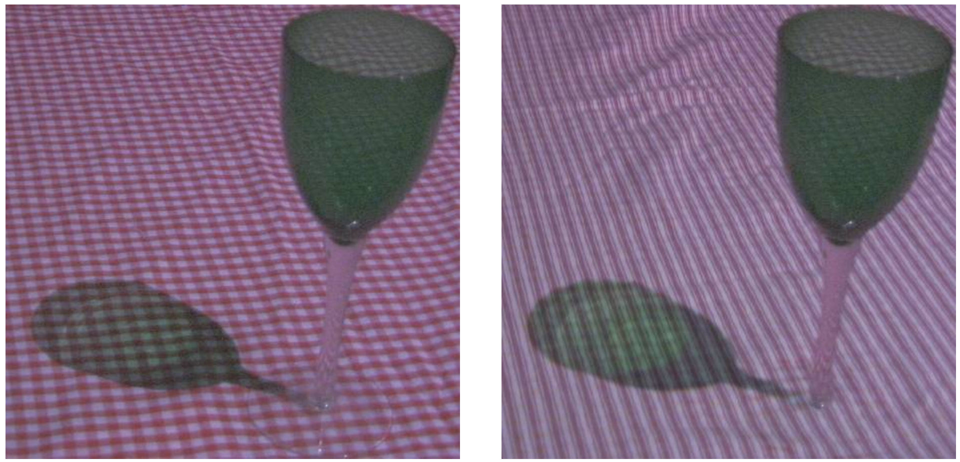
Just replacing pixels rarely works



Binary mask

Problems: boundries & transparency (shadows)

Two Problems:



Semi-transparent objects

Pixels too large

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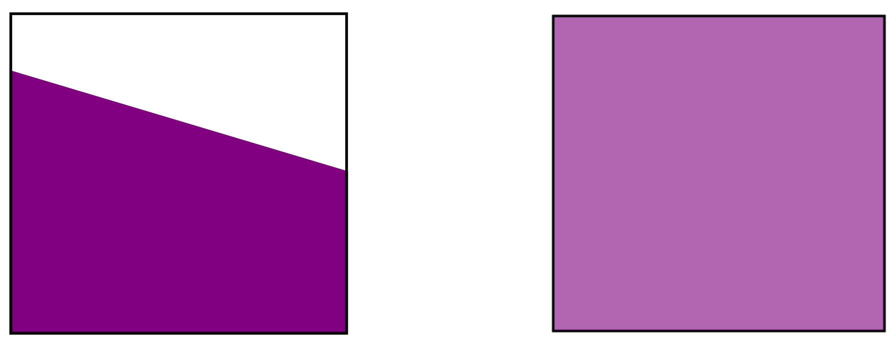
Solution: alpha channel

- Add one more channel:
  - Image(R,G,B,alpha)
- Encodes transparency (or pixel coverage):
  - Alpha = 1: opaque object (complete coverage)
  - Alpha = 0: transparent object (no coverage)
  - 0<Alpha<1: semi-transparent (partial coverage)
- Example: alpha = 0.3



Partial coverage or semi-transparency

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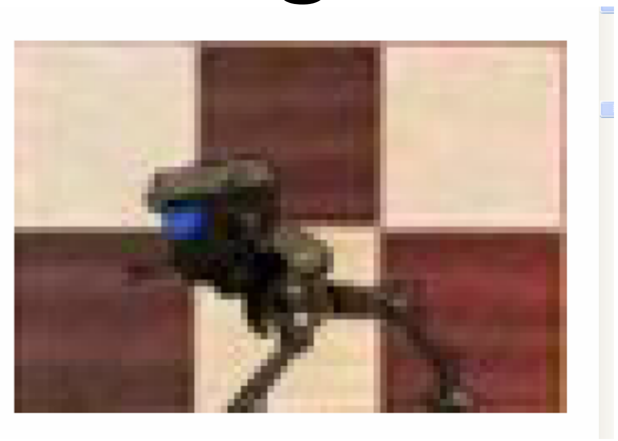
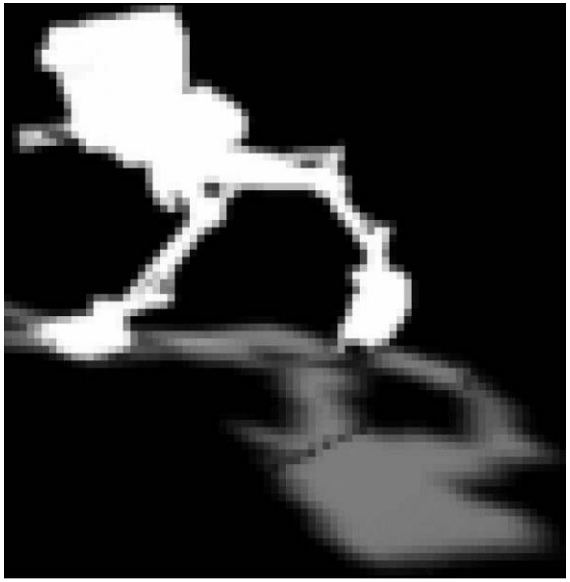
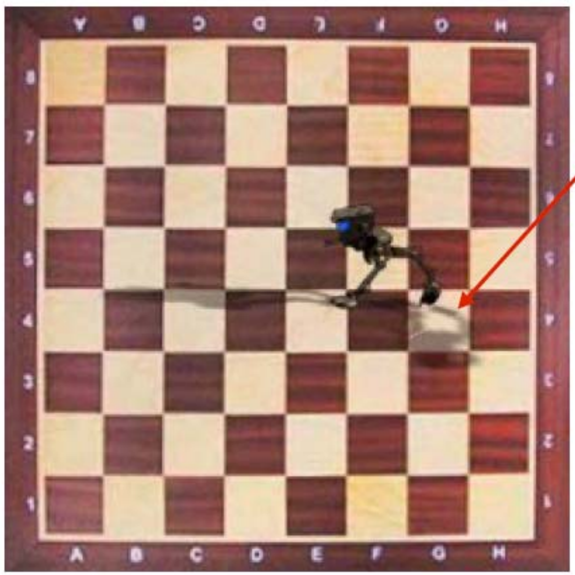
Alpha Blending



$$I_{comp} = \alpha I_{fg} + (1-\alpha) I_{bg}$$

alpha
mask





shadow

Multiple Alpha Blending

So far we assumed that one image (background) is opaque.

If blending semi-transparent sprites (the "A over B" operation):

$$I_{comp} = \alpha_a I_a + (1-\alpha_a)\alpha_b I_b$$

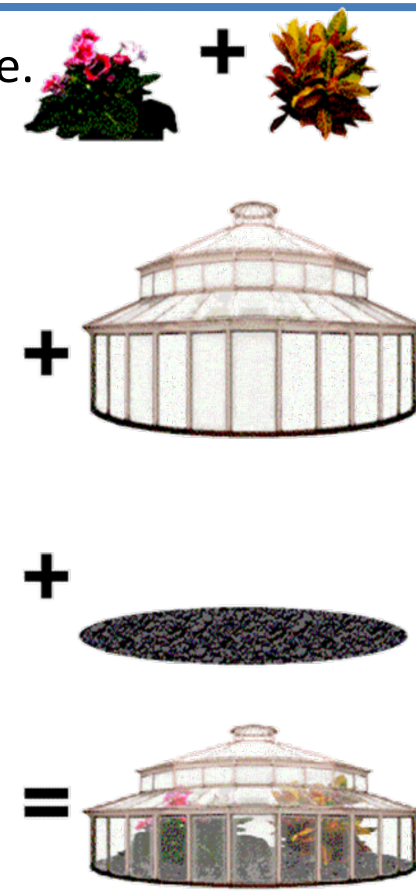
$$\alpha_{comp} = \alpha_a + (1-\alpha_a)\alpha_b$$

Note: sometimes alpha is premultiplied:

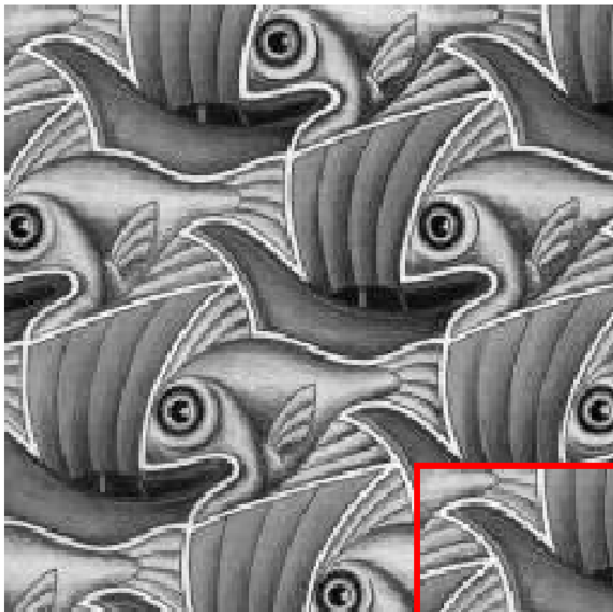
im(αR,αG,αB,α):

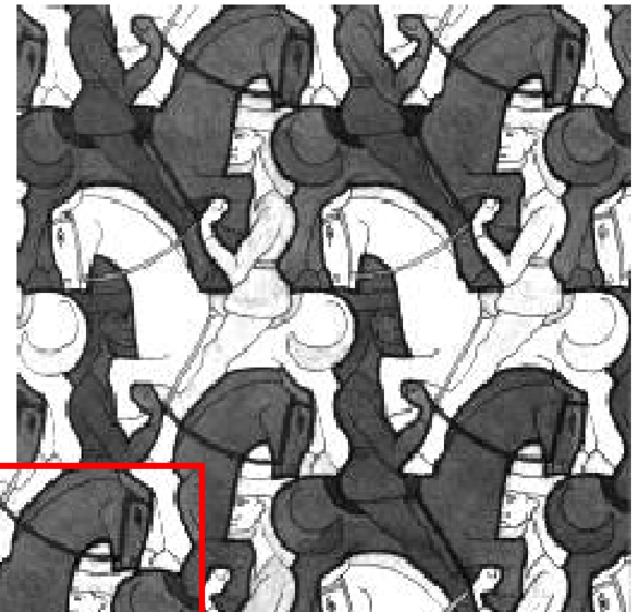
$$I_{comp} = I_a + (1-\alpha_a)I_b$$

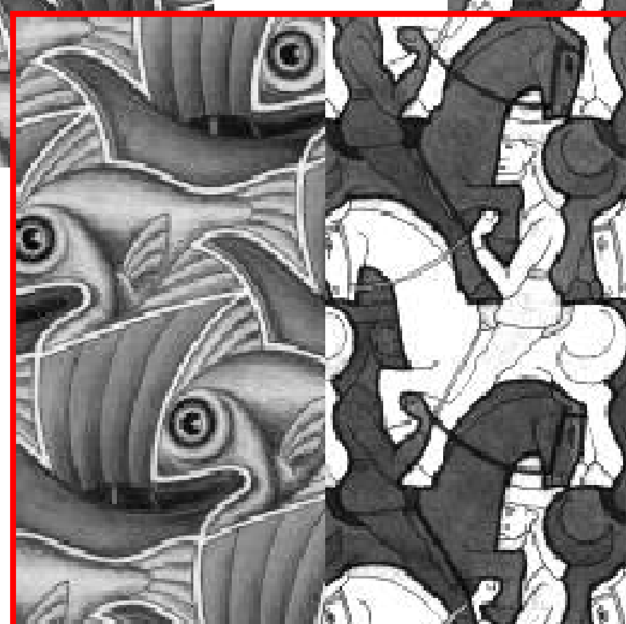
(same for alpha!)



Alpha Hacking…

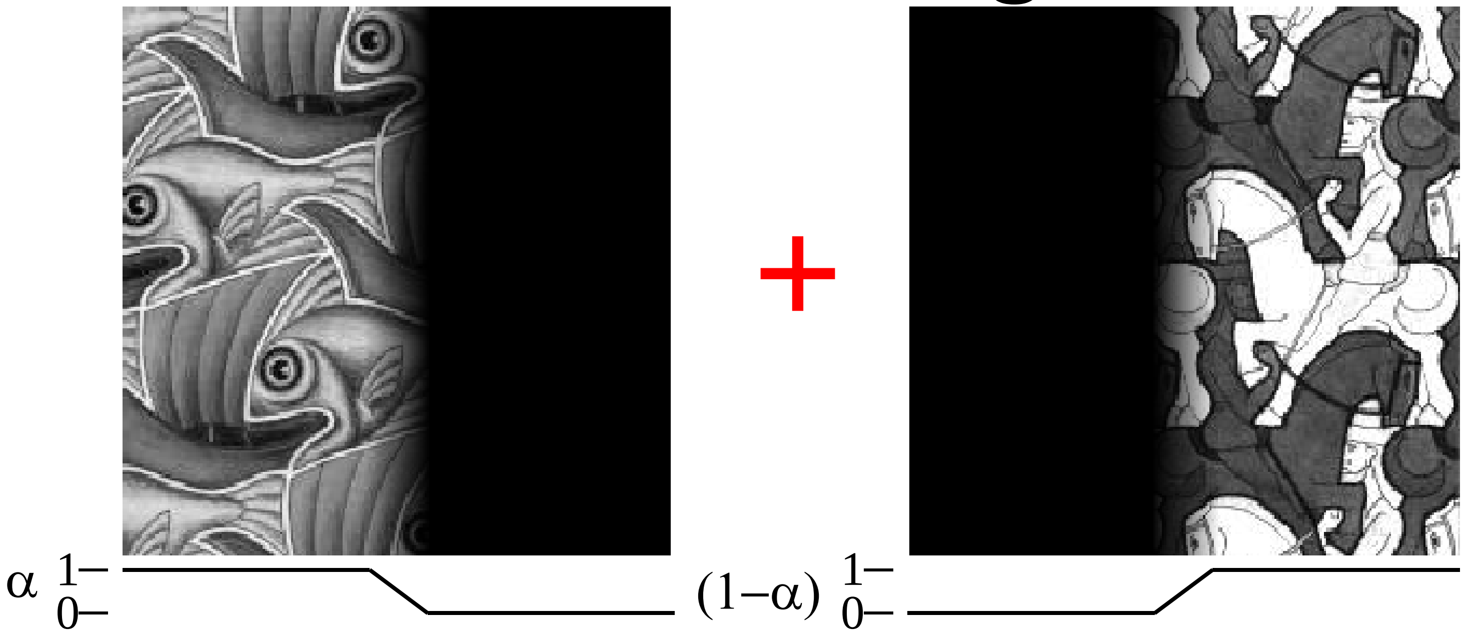


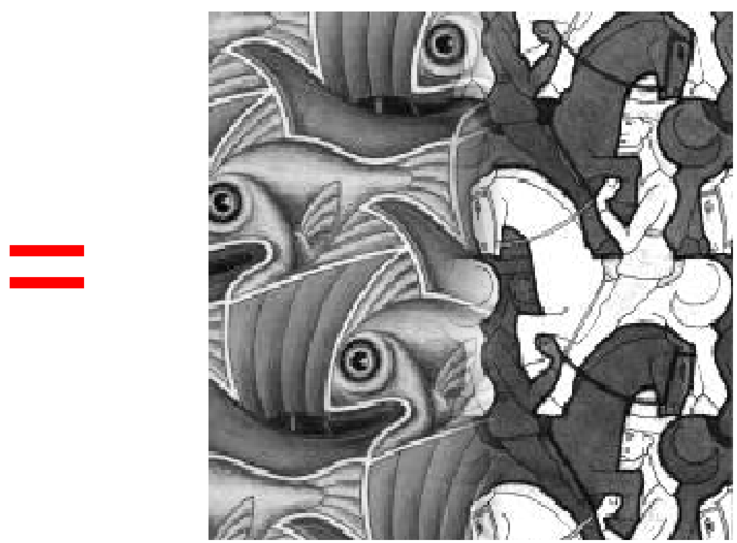




No physical interpretation,
but it smoothes the seams

Feathering





Encoding as transparency

$$I_{blend} = \alpha I_{left} + (1-\alpha) I_{right}$$

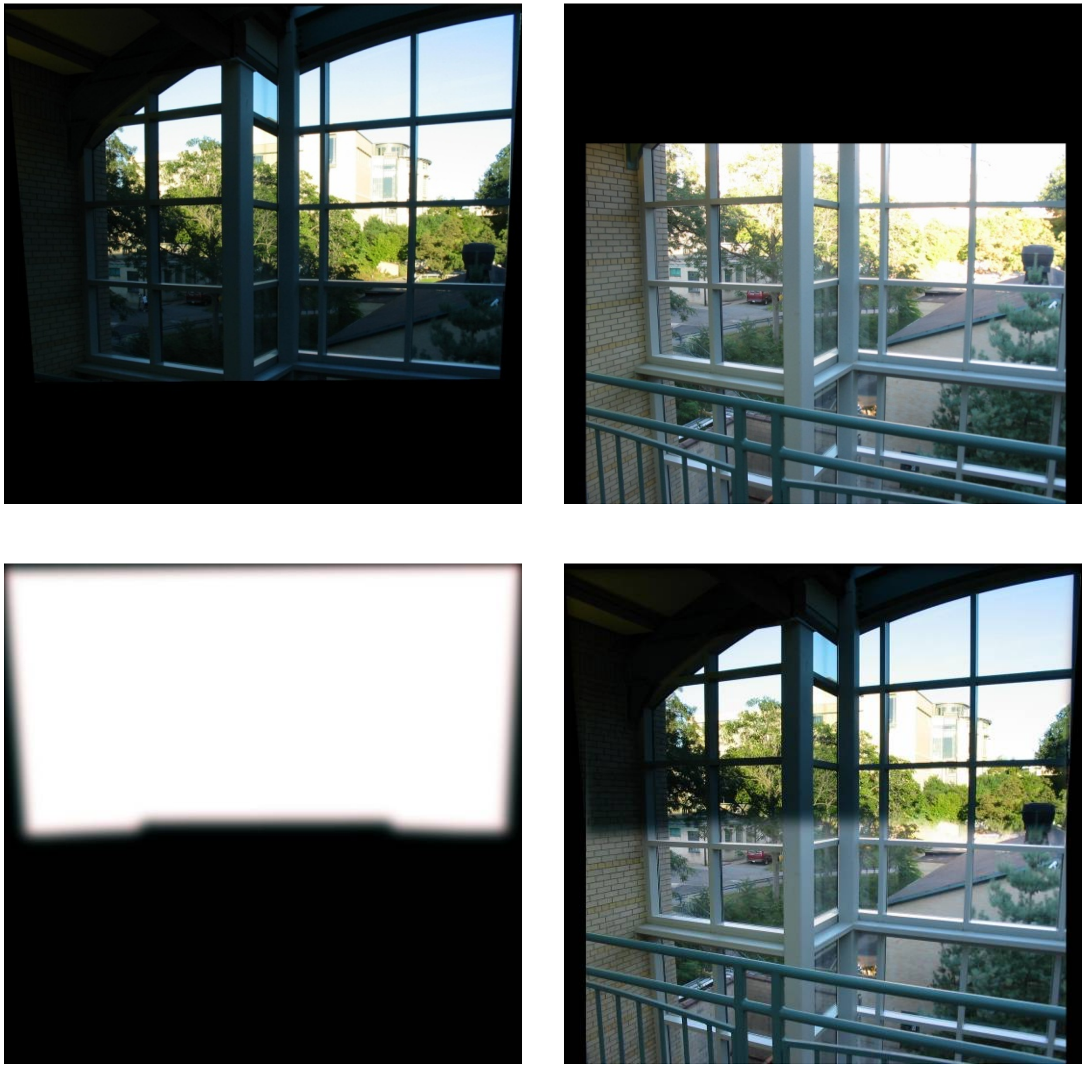
Setting alpha: simple averaging

Alpha = .5 in overlap region

Setting alpha: center seam

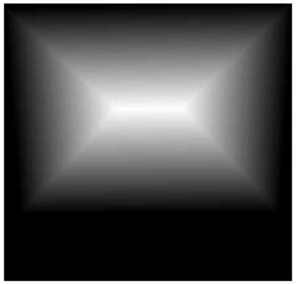
Alpha = logical(dtrans1>dtrans2)

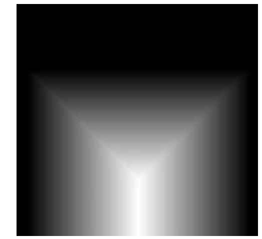
Setting alpha: blurred seam



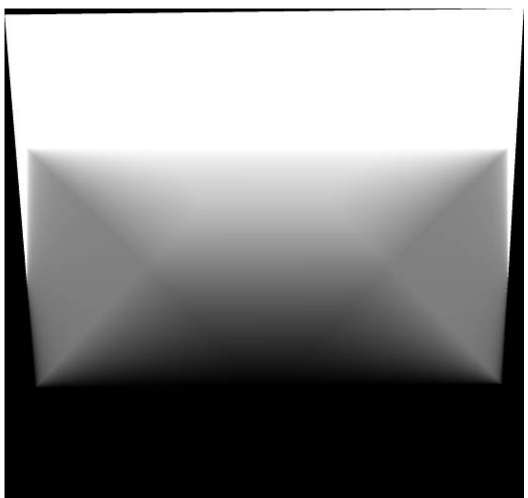
Alpha = blurred

Setting alpha: center weighting





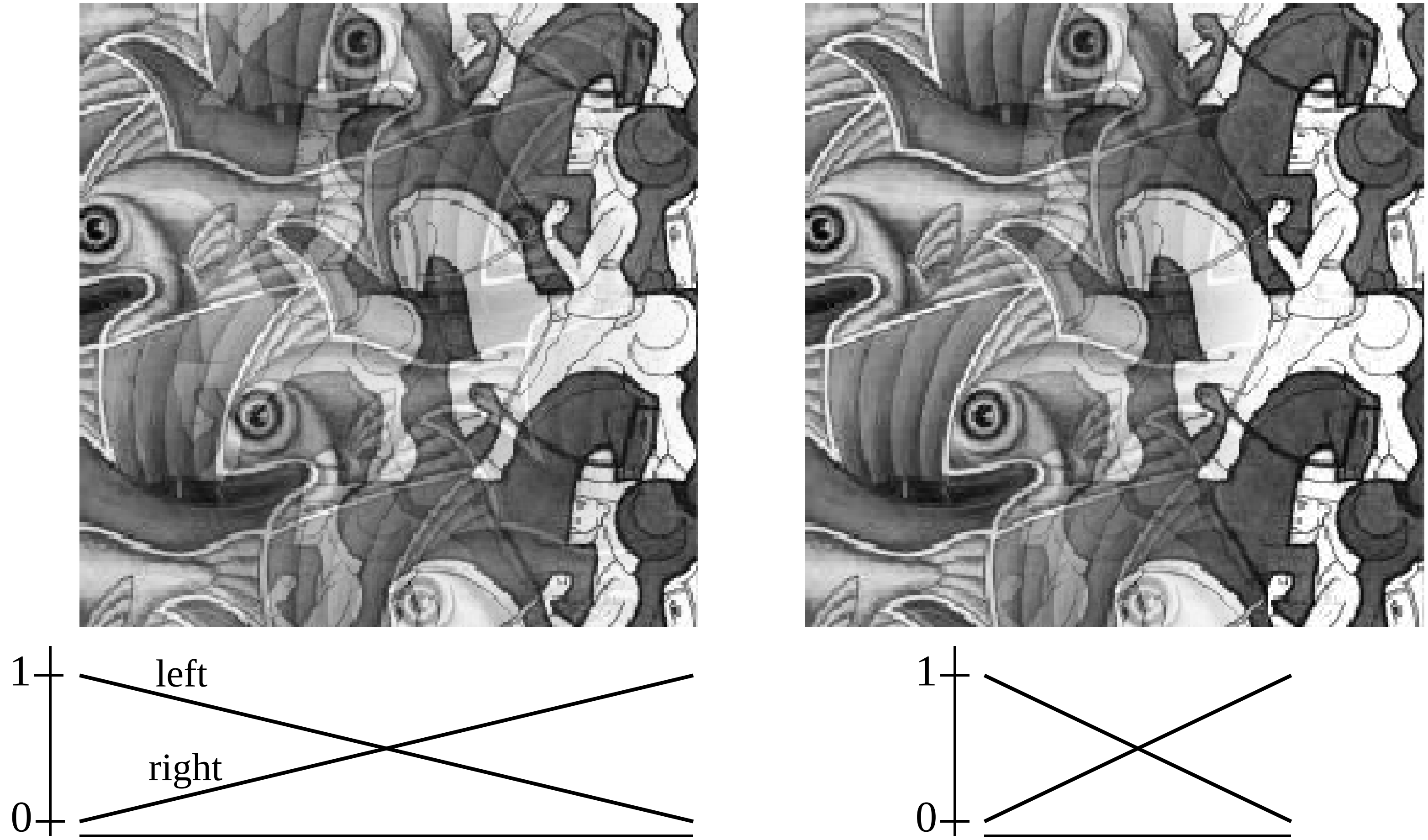
Distance transform



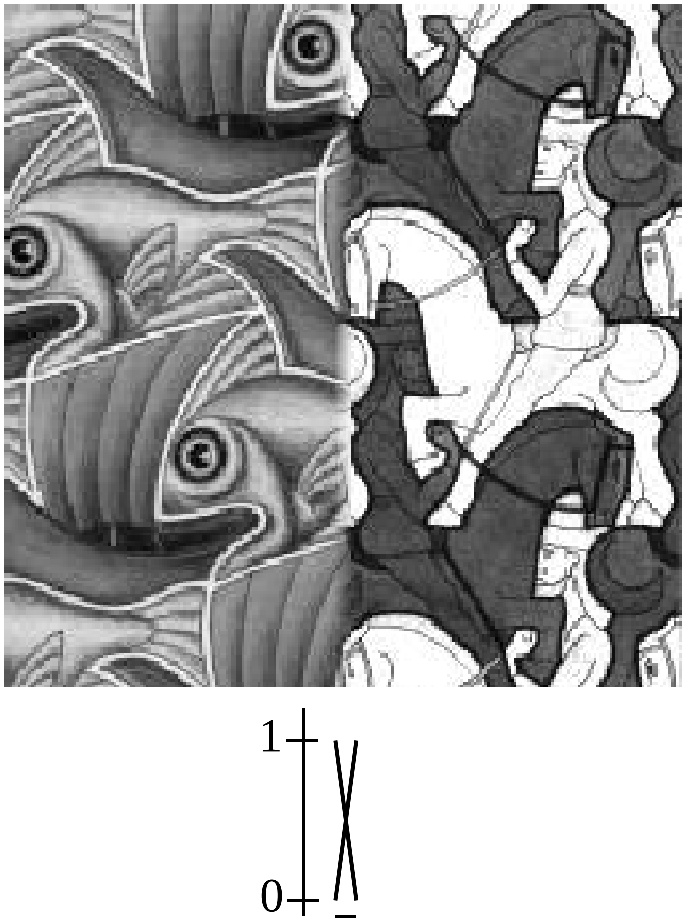
Ghost!

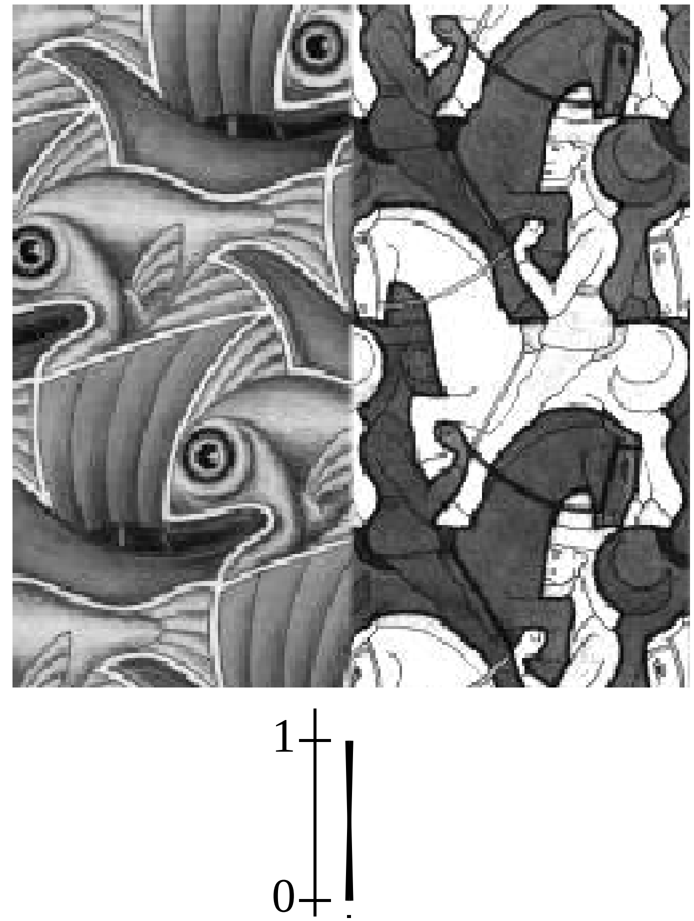
Alpha = dtrans1 / (dtrans1+dtrans2)

Affect of Window Size

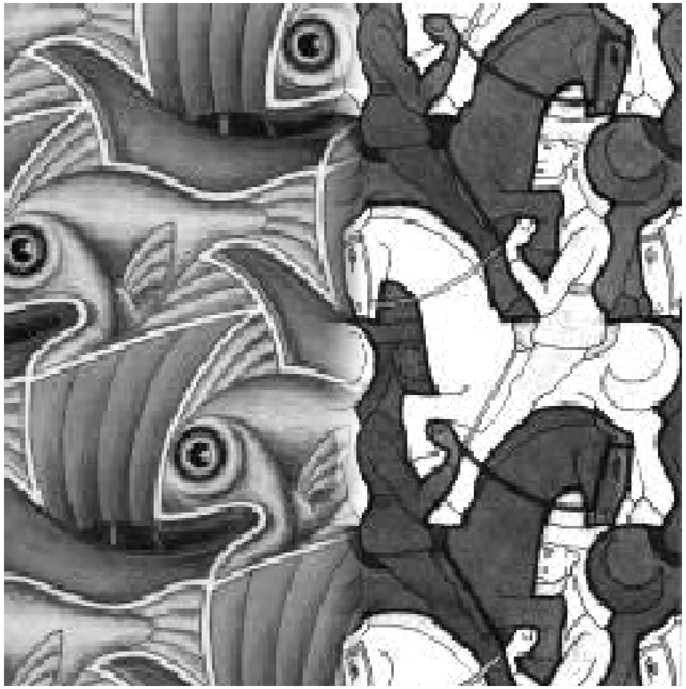


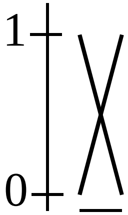
Affect of Window Size





Good Window Size





“Optimal” Window: smooth but not ghosted

What is the Optimal Window?

To avoid seams

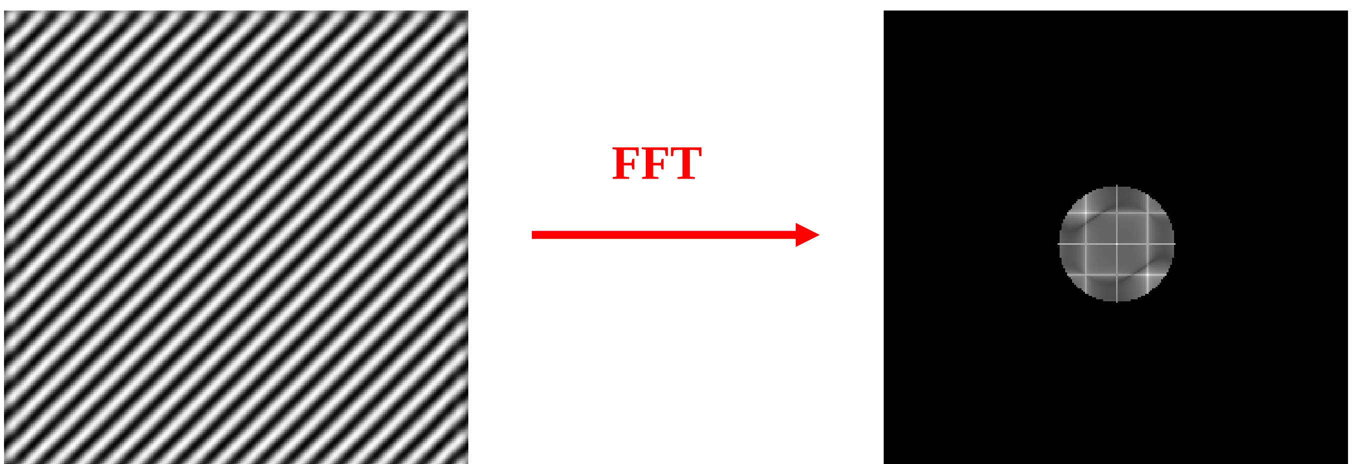
window = size of largest prominent feature

To avoid ghosting

window <= 2*size of smallest prominent feature

Natural to cast this in the *Fourier domain*

- largest frequency <= 2*size of smallest frequency
- image frequency content should occupy one “octave” (power of two)



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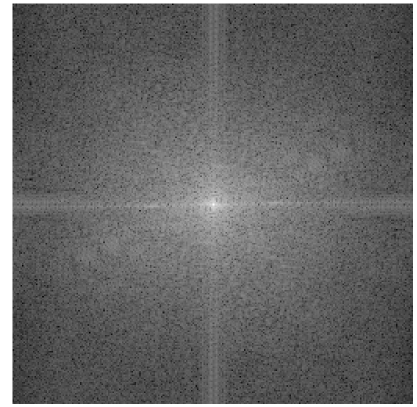
What if the Frequency Spread is Wide

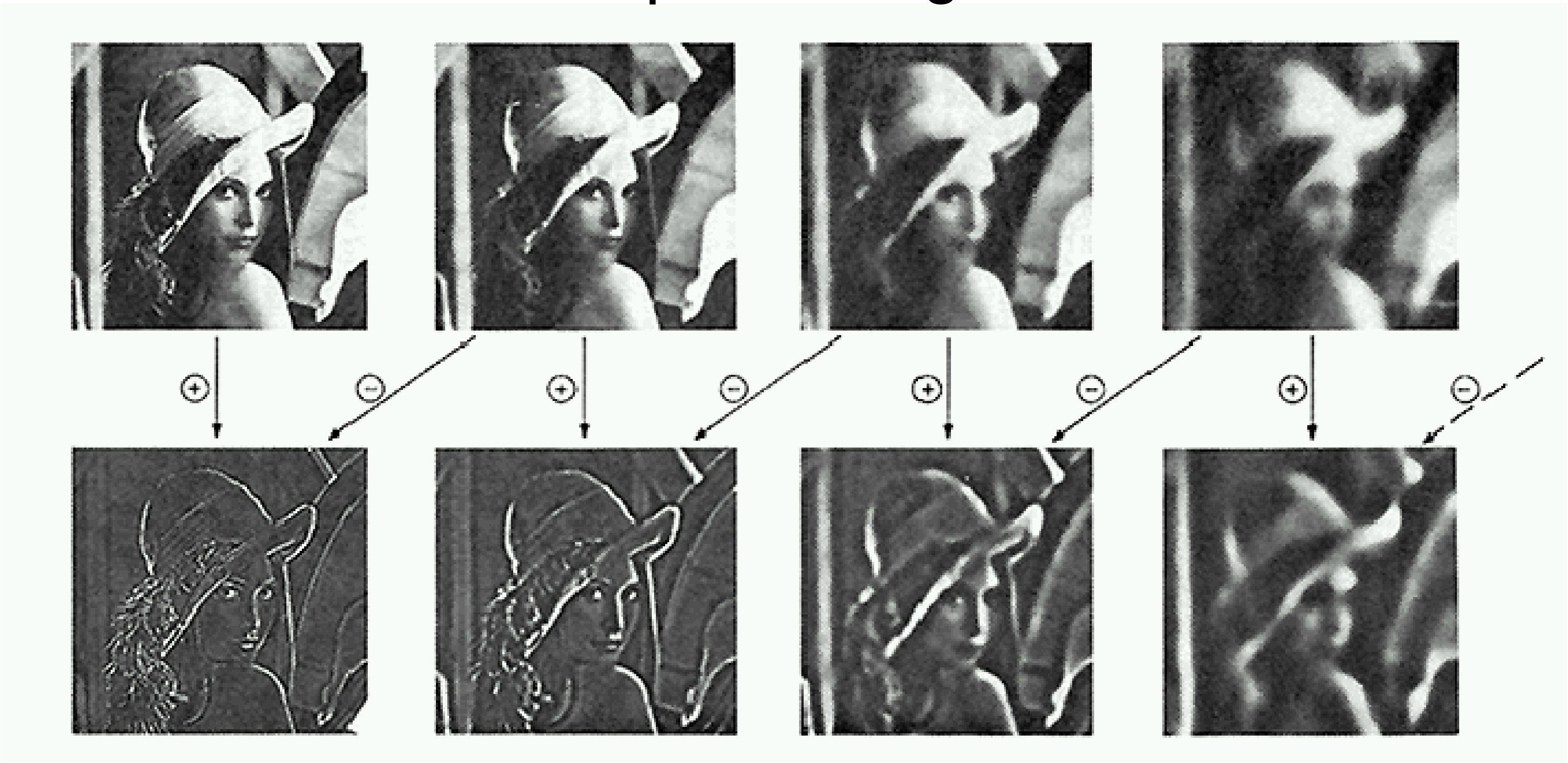
FFT →



- Idea (Burt and Adelson)
  - Compute $F_{left} = FFT(I_{left})$, $F_{right} = FFT(I_{right})$
  - Decompose Fourier image into octaves (bands)
    - $F_{left} = F_{left}^1 + F_{left}^2 + \ldots$
  - Feather corresponding octaves F_{left}^i with F_{right}^i
    - Can compute inverse FFT and feather in spatial domain
  - Sum feathered octave images in frequency domain
- Better implemented in *spatial domain*

Octaves in the Spatial Domain

Lowpass Images



Bandpass Images

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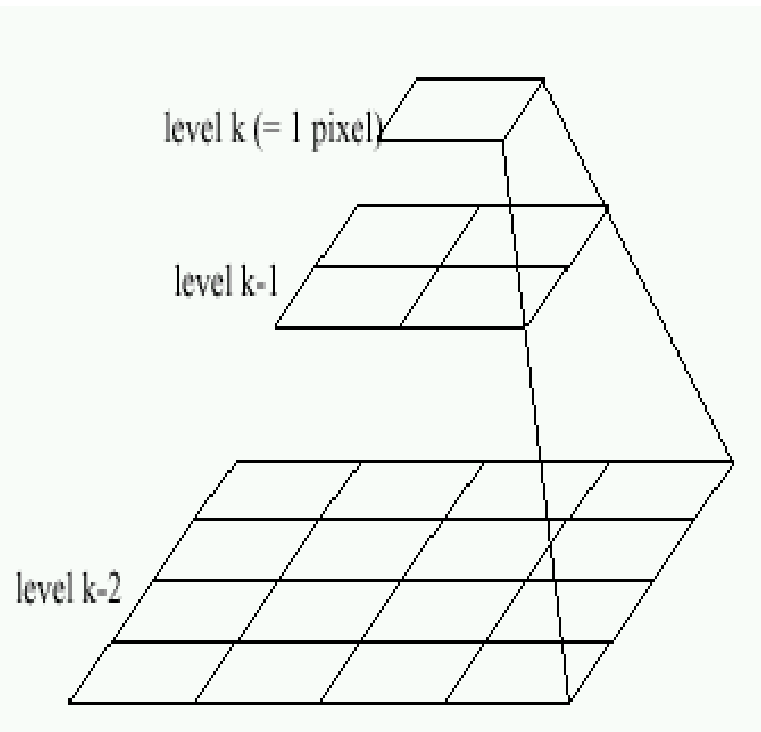
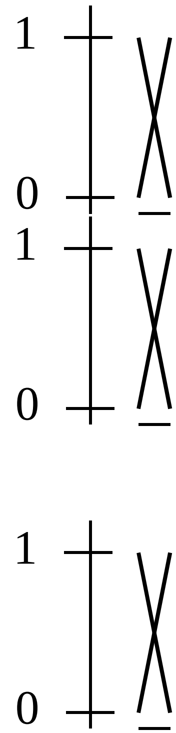
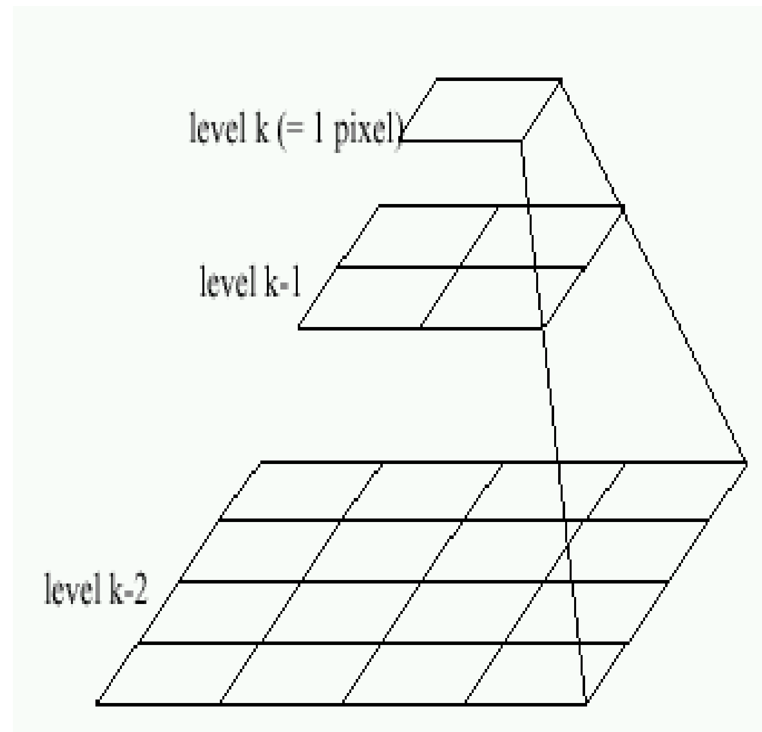
Pyramid Blending





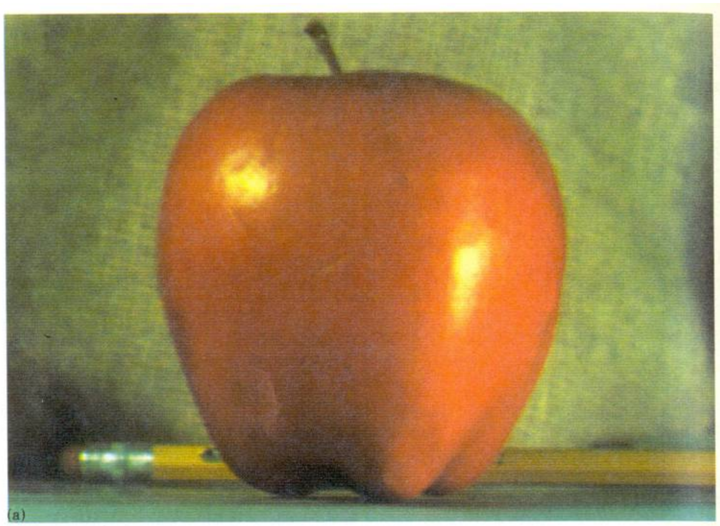


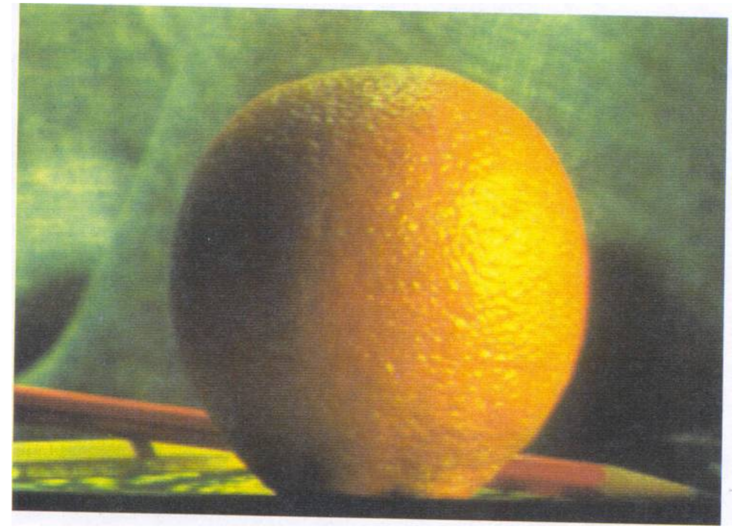
Left pyramid

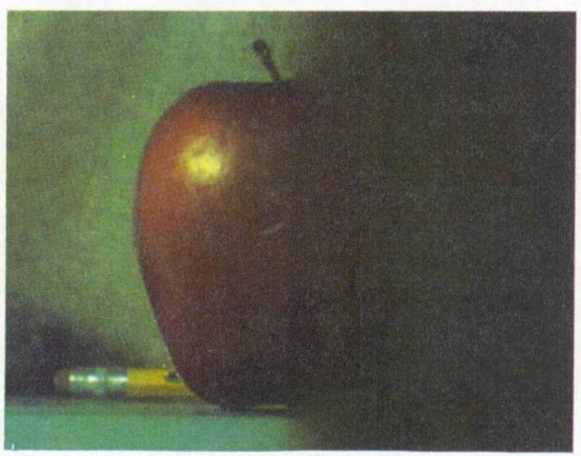
blend

Right pyramid

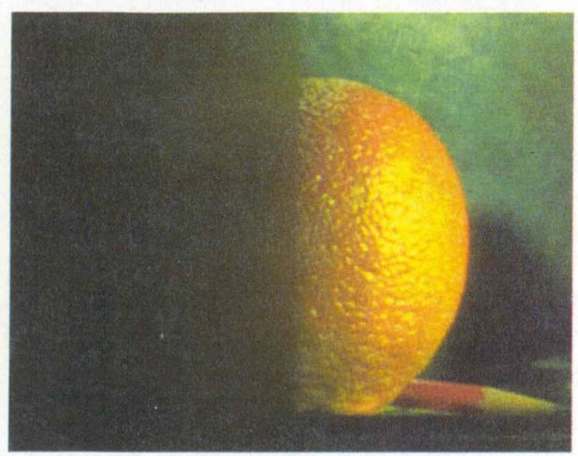
Pyramid Blending



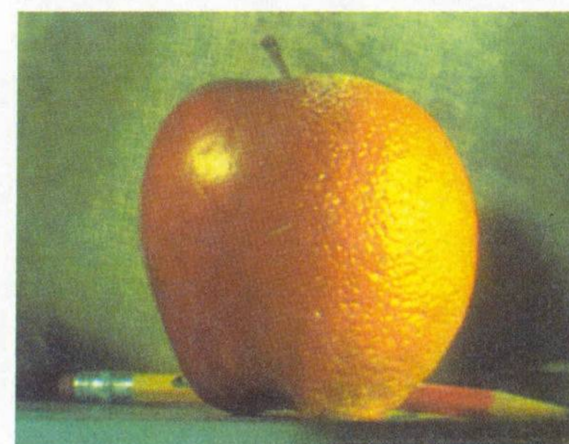




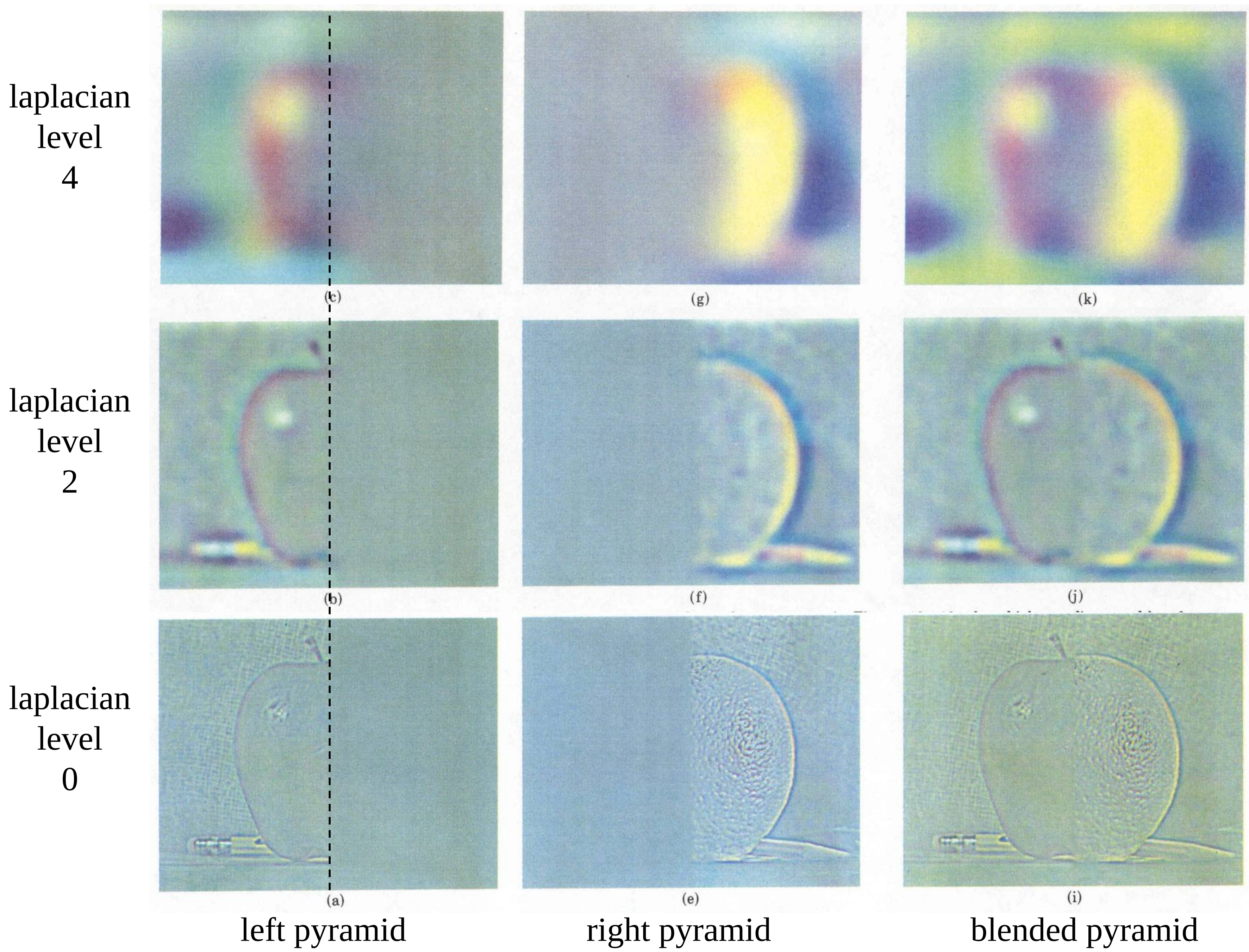
(d)



(h)



(l)

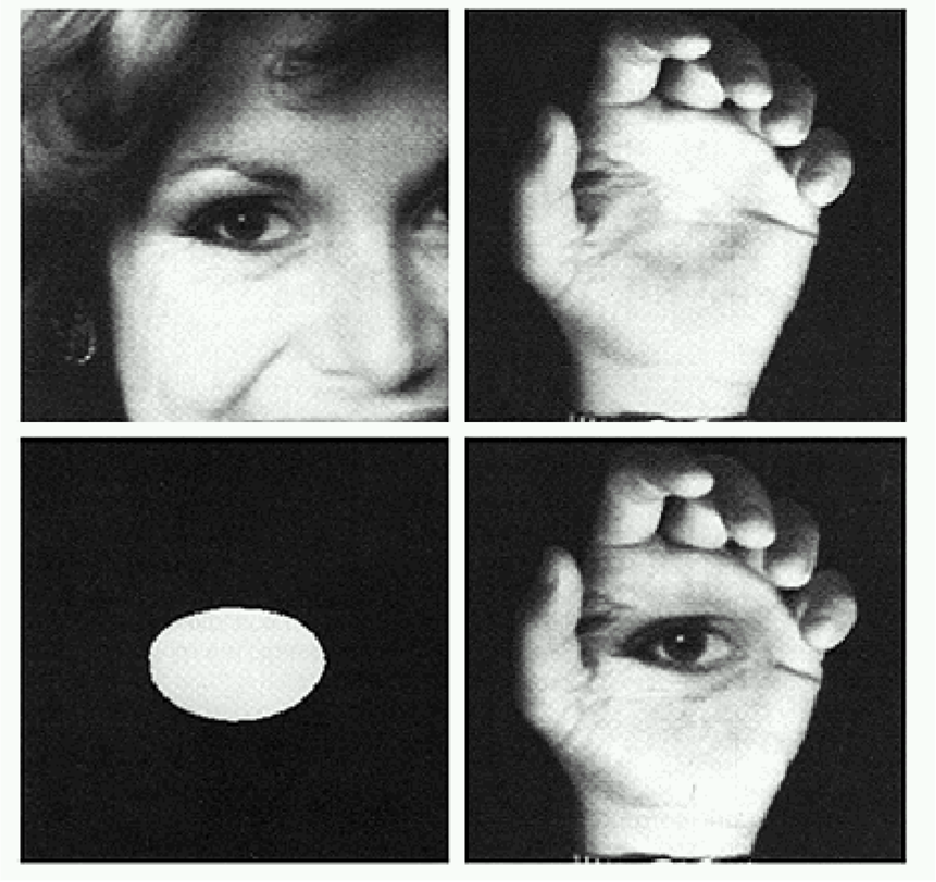

laplacian level 4
laplacian level 2
laplacian level 0
(c)
(g)
(k)
(b)
(f)
(j)
(a)
(e)
(i)
left pyramid
right pyramid
blended pyramid

Laplacian Pyramid: Blending

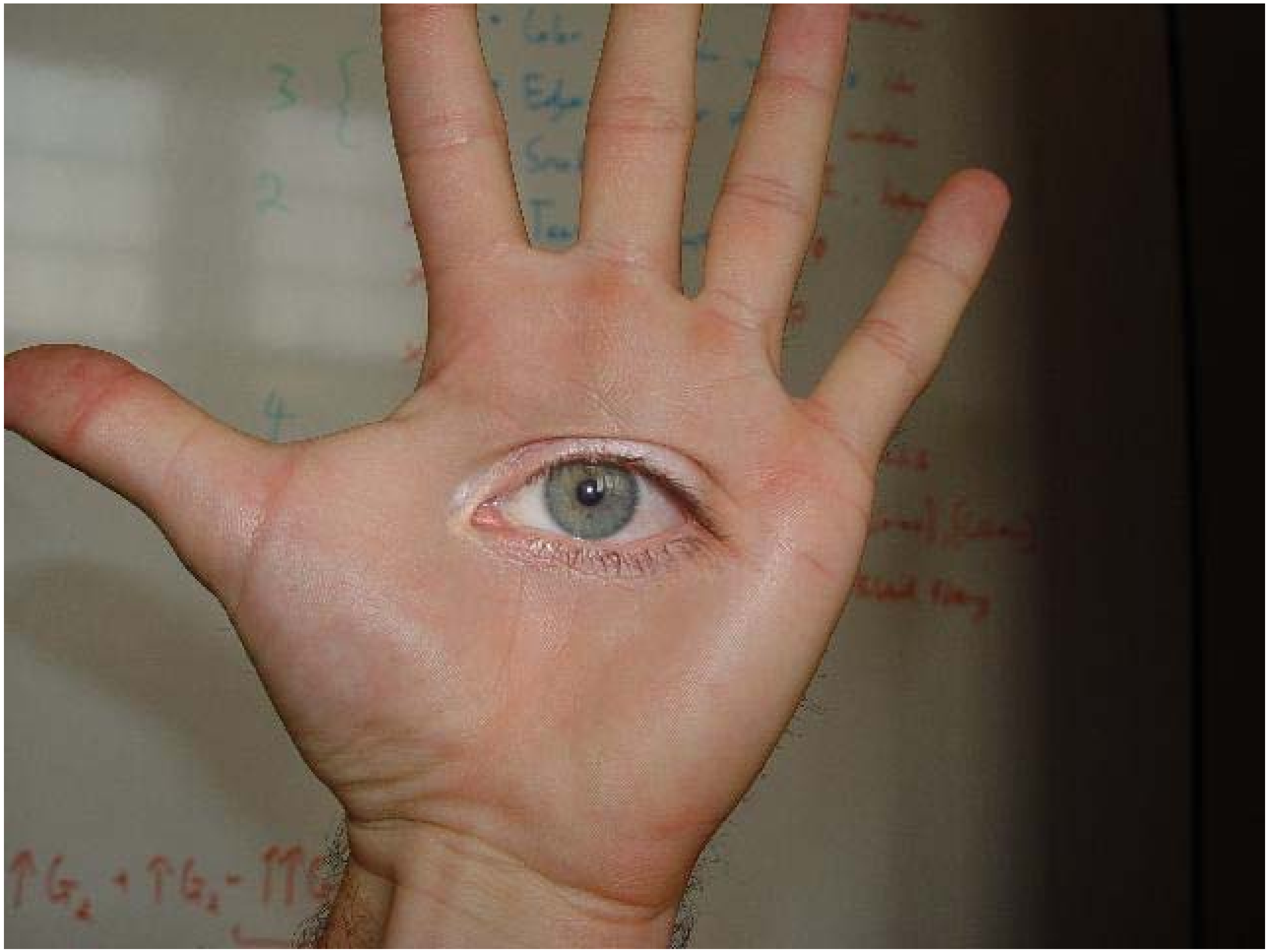
General Approach:

1. Build Laplacian pyramids *LA* and *LB* from images *A* and *B*
2. Build a Gaussian pyramid *GR* from selected region *R*
3. Form a combined pyramid *LS* from *LA* and *LB* using nodes of *GR* as weights:
   - *LS(i,j) = GR(I,j,)*LA(I,j) + (1-GR(I,j))*LB(I,j)*
4. Collapse the *LS* pyramid to get the final blended image

Blending Regions



Horror Photo



© david dmartin (Boston College)

Results from CMU class (fall 2005)

© Chris Cameron

Season Blending (St. Petersburg)

Season Blending (St. Petersburg)

Simplification: Two-band Blending

- Brown & Lowe, 2003
  - Only use two bands: high freq. and low freq.
  - Blends low freq. smoothly
  - Blend high freq. with no smoothing: use binary alpha

2-band Blending

Low frequency (λ > 2 pixels)

High frequency (λ < 2 pixels)

Linear Blending

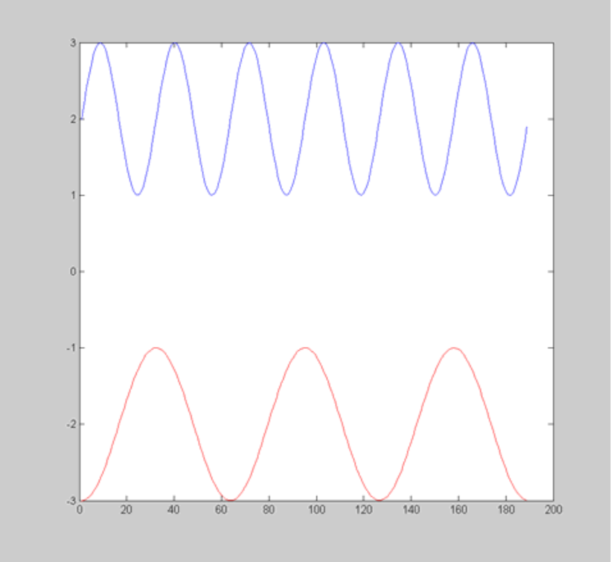
2-band Blending

Gradient Domain

- In Pyramid Blending, we decomposed our image into 2nd derivatives (Laplacian) and a low-res image
- Let us now look at 1st derivatives (gradients):
  - No need for low-res image
    - captures everything (up to a constant)
  - Idea:
    - Differentiate
    - Blend
    - Reintegrate

Gradient Domain blending (1D)

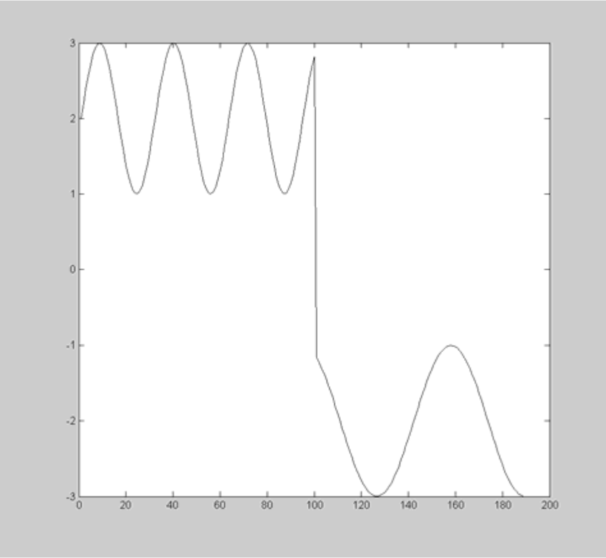
Two signals

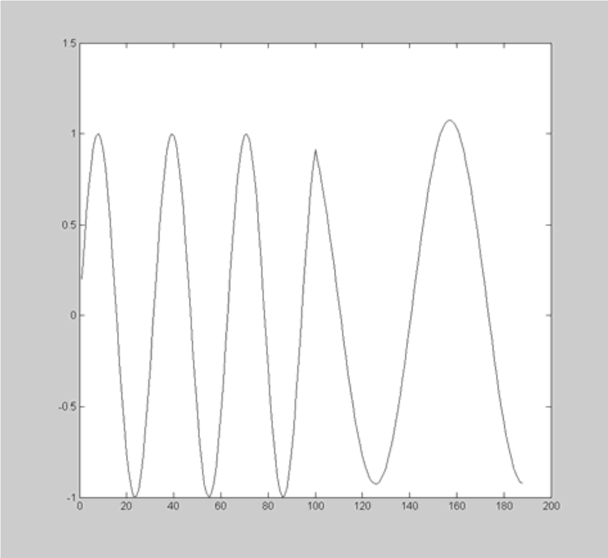


bright

dark

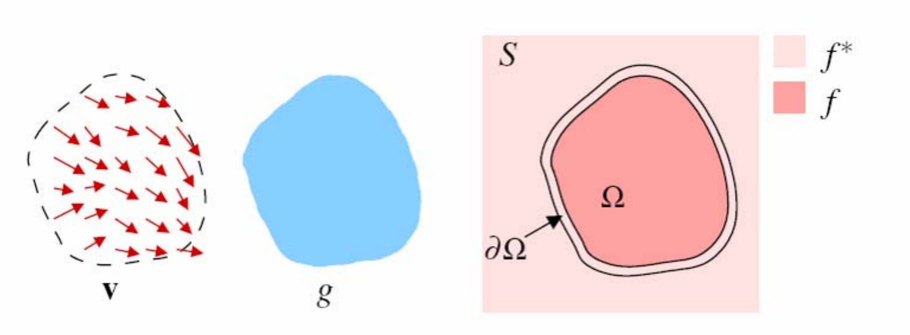
Regular blending





Blending derivatives

Gradient Domain Blending (2D)



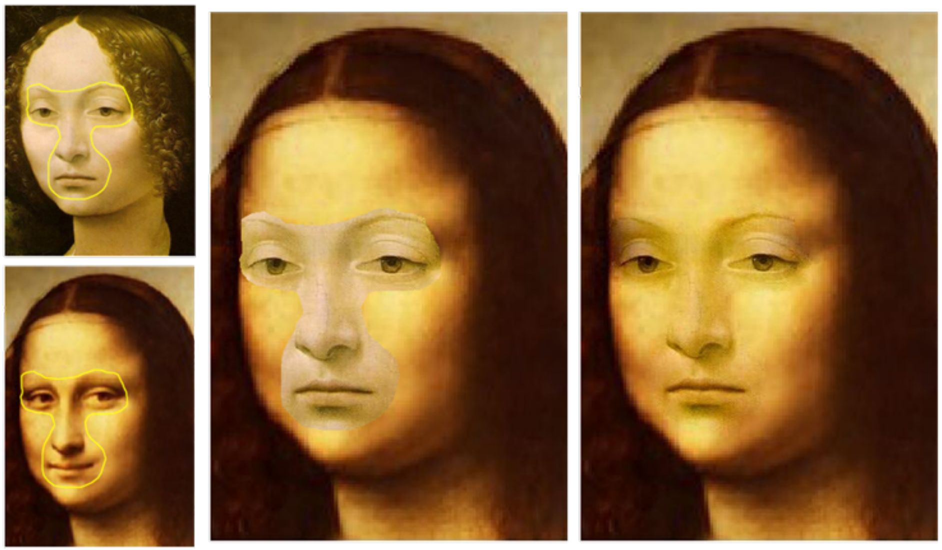
- Trickier in 2D:
  - Take partial derivatives dx and dy (the gradient field)
  - Fidle around with them (smooth, blend, feather, etc)
  - Reintegrate
    - But now integral(dx) might not equal integral(dy)
  - Find the most agreeable solution
    - Equivalent to solving Poisson equation
    - Can use FFT, deconvolution, multigrid solvers, etc.

Perez et al., 2003

sources destinations cloning seamless cloning

sources/destinations cloning seamless cloning

Perez et al, 2003



source/destination cloning seamless cloning

editing

Limitations:

- Can’t do contrast reversal (gray on black -> gray on white)
- Colored backgrounds “bleed through”
- Images need to be very well aligned

Don’t blend, CUT!

Moving objects become ghosts

So far we only tried to blend between two images. What about finding an optimal seam?

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Davis, 1998

Segment the mosaic

- Single source image per segment
- Avoid artifacts along boundries
  - Dijkstra's algorithm

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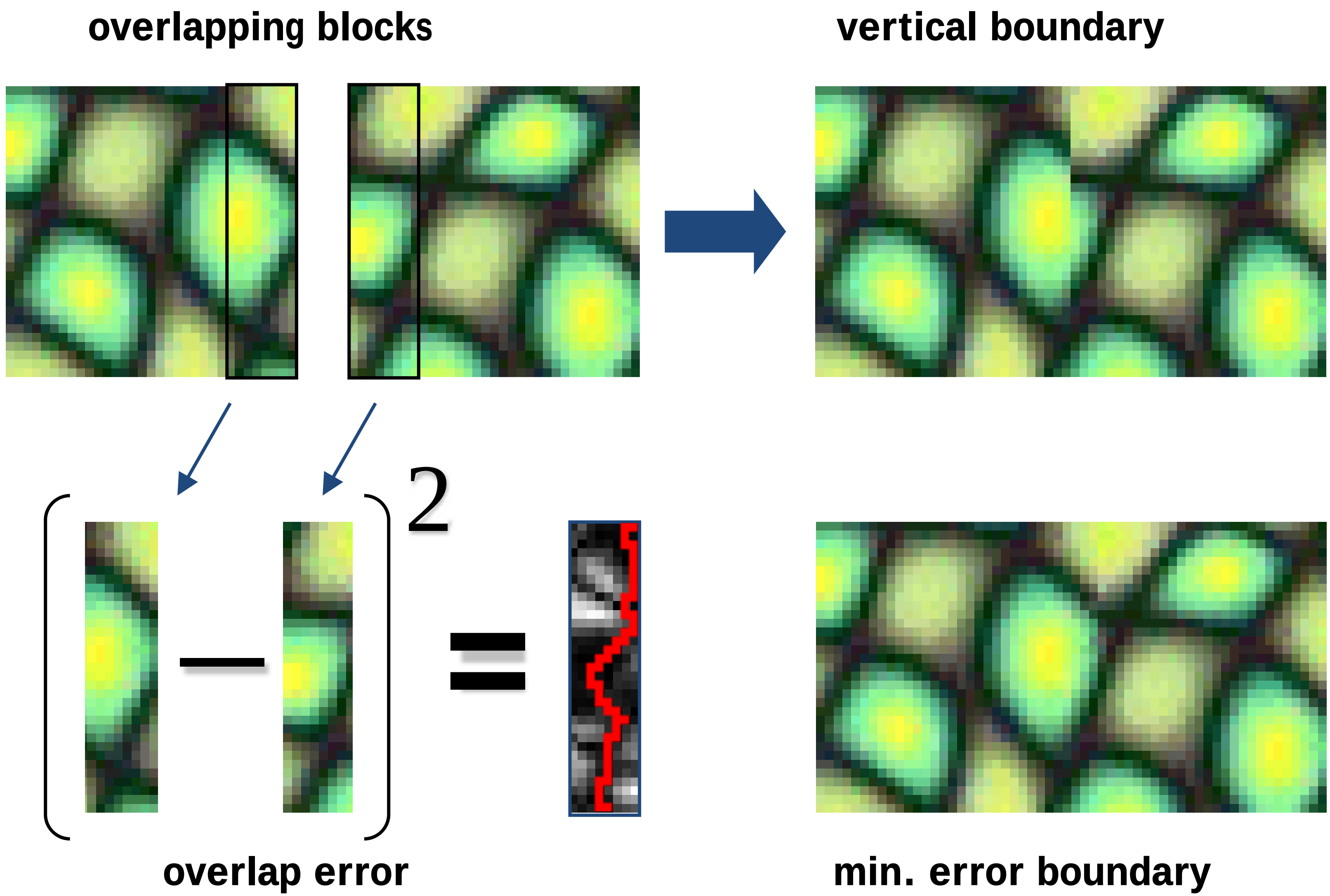
Minimal error boundary



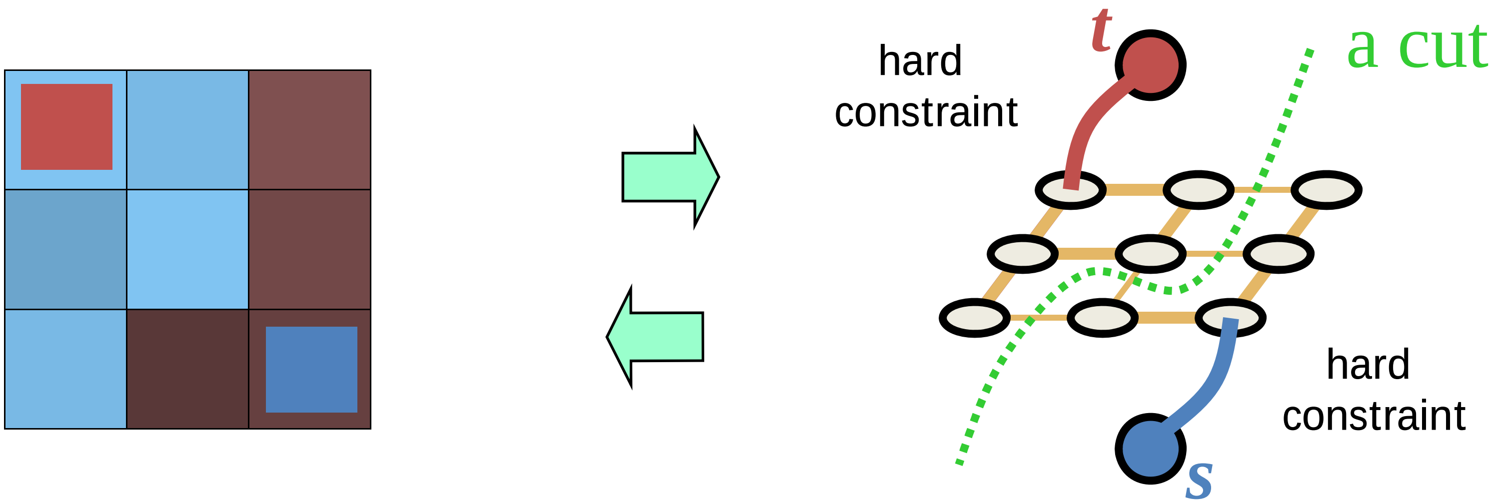
Graphcuts

What if we want similar “cut-where-things-agree” idea, but for closed regions?

– Dynamic programming can’t handle loops

Graph cuts

(simple example à la Boykov&Jolly, ICCV’01)



Minimum cost cut can be computed in polynomial time

(max-flow/min-cut algorithms)

Kwatra et al, 2003

Actually, for this example, DP will work just as well…

Lazy Snapping

(a) Girl (4/2/12) (b) Ballet (4/7/14) (c) Boy (6/2/13)

(c) Grandpa (4/2/11) (d) Twins (4/4/12)

Interactive segmentation using graphcuts

Putting it all together

Compositing images/mosaics

- Have a clever blending function
  - Feathering
  - Center-weighted
  - blend different frequencies differently
  - Gradient based blending
- Choose the right pixels from each image
  - Dynamic programming – optimal seams
  - Graph-cuts

Now, let's put it all together:

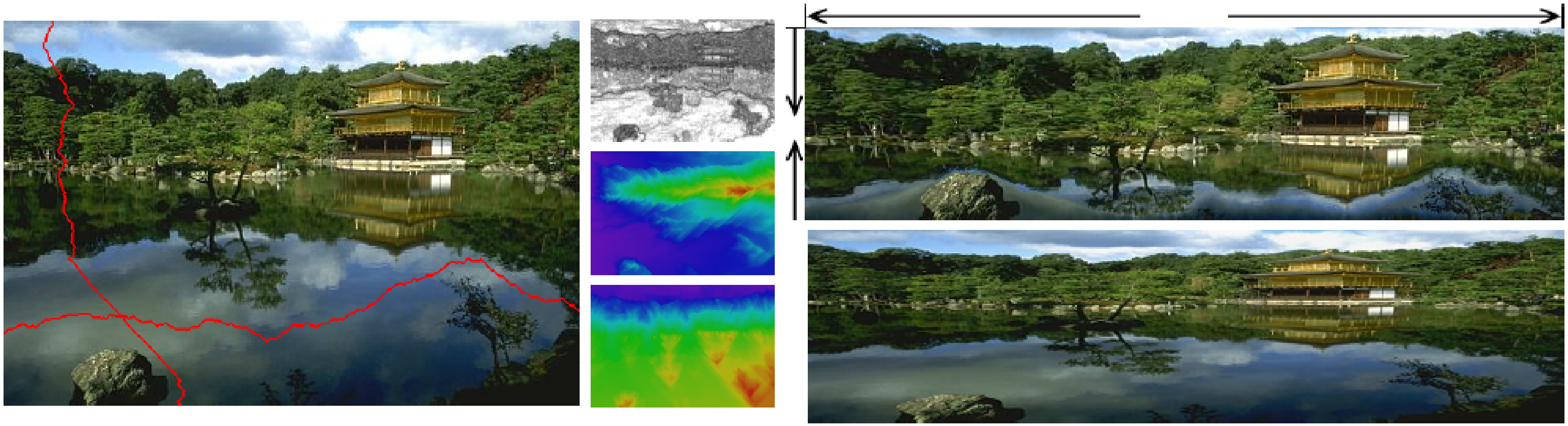
- Interactive Digital Photomontage, 2004 (video)

Interactive Digital Photomontage

Aseem Agarwala, Mira Dontcheva
Maneesh Agrawala, Steven Drucker, Alex Colburn
Brian Curless, David Salesin, Michael Cohen

Image resizing

- Dynamic Range, HDR imaging, tone mapping



Next week

- Dynamic Range, HDR imaging, tone mapping