

Image Alignment and Mosaicing

Image Alignment Applications

- Local alignment:
 - Tracking
 - Stereo
- Global alignment:
 - Camera jitter elimination
 - Image enhancement
 - Panoramic mosaicing

Image Enhancement



Original



Enhanced

Panoramic Mosaicing



Gigapixel panoramas & images

The image shows two overlapping browser windows. The left window displays the Microsoft Research HD View Beta website. The right window shows a zoomed-in view of a medical image, likely a histological slide, with a mouse cursor pointing to a specific area.

Microsoft Research HD View Beta

Microsoft Research

About HD View | Sites using HD View | Create your own HD View content | FAQs | Help | Forum | Blog

HD View is a new viewer developed by Microsoft Research's Interactive Visual Media group to aid in the display and interaction with very large images. Why use HD View?

Mapping / Tourism / WWT

To get started with HD View, click on the image below.
(If you have never used HD View, you will be prompted to install an ActiveX control.)

The panorama at right contains approximately 4 Gigapixels. It was stitched from 800 individual images. Click on the image to explore this and other images using HD View. A description of how these images were made can be found here.

Explore other BIG images at XRez.com,

and by Bradford Bohonus.

Medical Imaging

Powered by Microsoft Research HD View

Panoramic Mosaicing

1. Align images
2. Merge overlapping regions



Correspondence Approaches

- Optical flow
- Correlation
- Correlation + optical flow
- Any of the above, iterated (e.g. Lucas-Kanade)
- Any of the above, coarse-to-fine
- Feature matching + RANSAC

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Optical Flow for Image Registration

- Compute local matches
- Least-squares fit to motion model
- Problem: outliers

Outlier Rejection

- Robust estimation: tolerant of outliers
- In general, methods based on absolute value rather than square:

$$\text{minimize } \sum |x_i - f|, \text{ not } \sum (x_i - f)^2$$

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Correlation / Search Methods

- Assume translation only
- Given images I_1, I_2
- For each translation (t_x, t_y) compute

$$c(I_1, I_2, \mathbf{t}) = \sum_i \sum_j \psi(I_1(i, j), I_2(i - t_x, j - t_y))$$

- Select translation that maximizes c
- Depending on window size, local or global

Cross-Correlation

- Statistical definition of correlation:

$$\psi(u, v) = uv$$

- Disadvantage: sensitive to local variations in image brightness

Normalized Cross-Correlation

- Normalize to eliminate brightness sensitivity:

$$\psi(u, v) = \frac{(u - \bar{u})(v - \bar{v})}{\sigma_u \sigma_v}$$

where

\bar{u} = average (u)

σ_u = standard deviation (u)

Sum of Squared Differences

- More intuitive measure:

$$\psi(u, v) \equiv -(u - v)^2$$

- Negative: higher values \rightarrow greater similarity
- Expand:

$$-(u - v)^2 \equiv -u^2 - v^2 + 2uv$$

Local vs. Global

- Correlation with local windows not too expensive
- High cost if window size = whole image

- But computation looks like convolution
 - FFT to the rescue!

Fourier Transform with Translation

$$\mathcal{F}(f(x + \Delta x, y + \Delta y)) = \mathcal{F}(f(x, y))e^{i(\omega_x \Delta x + \omega_y \Delta y)}$$

Fourier Transform with Translation

- Therefore, if I_1 and I_2 differ by translation,

$$\mathcal{F}(I_1(x, y)) = \mathcal{F}(I_2(x, y))e^{i(\omega_x\Delta x + \omega_y\Delta y)}$$

$$\frac{F_1}{F_2} = e^{i(\omega_x\Delta x + \omega_y\Delta y)}$$

- So, $\mathcal{F}^{-1}(F_1/F_2)$ will have a peak at $(\Delta x, \Delta y)$

Phase Correlation

- In practice, use cross power spectrum

$$\frac{F_1 F_2^*}{|F_1 F_2^*|}$$

- Compute inverse FFT, look for peaks
- [Kuglin & Hines 1975]

Phase Correlation

- Advantages
 - Fast computation
 - Low sensitivity to global brightness changes
(since equally sensitive to all frequencies)

Phase Correlation

- Disadvantages
 - Sensitive to white noise
 - No robust version
 - Translation only
 - Extensions to rotation, scale
 - But **not** local motion
 - Not too bad in practice with small local motions

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Correlation plus Optical Flow

- Use e.g. phase correlation to find average translation (may be large)
- Use optical flow to find local motions

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Correspondence Approaches

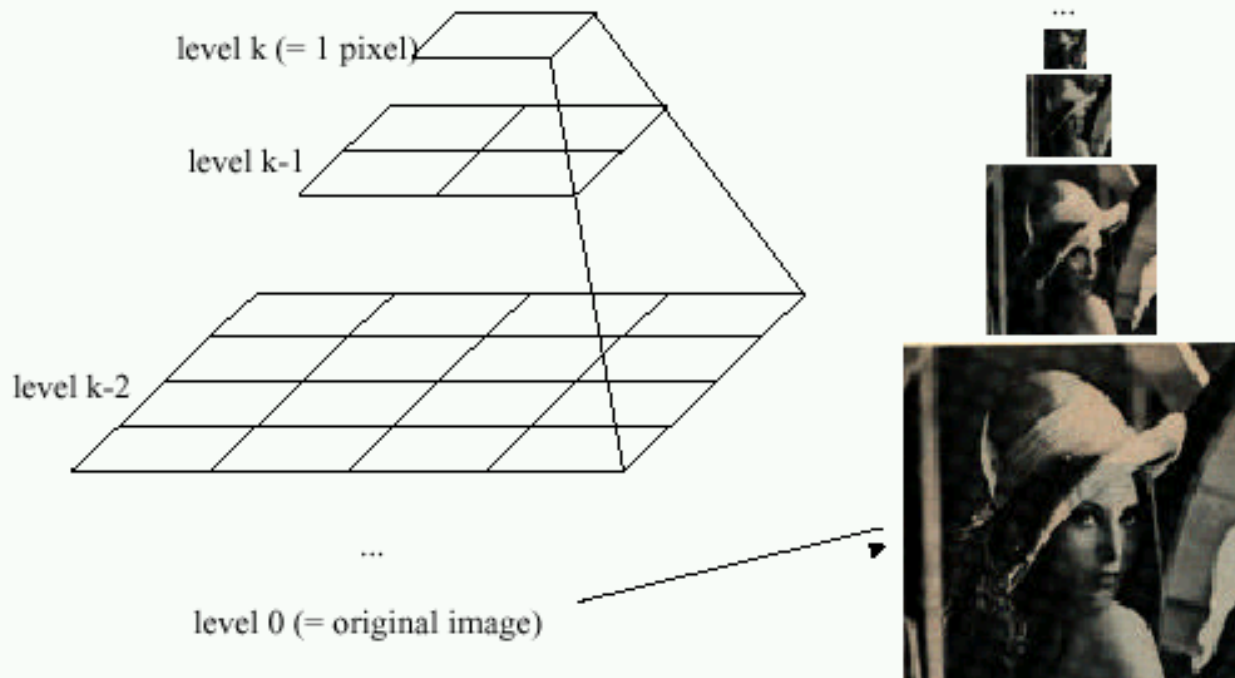
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Image Pyramids

- Pre-filter images to collect information at different scales
- More efficient computation, allows larger motions

Image Pyramids

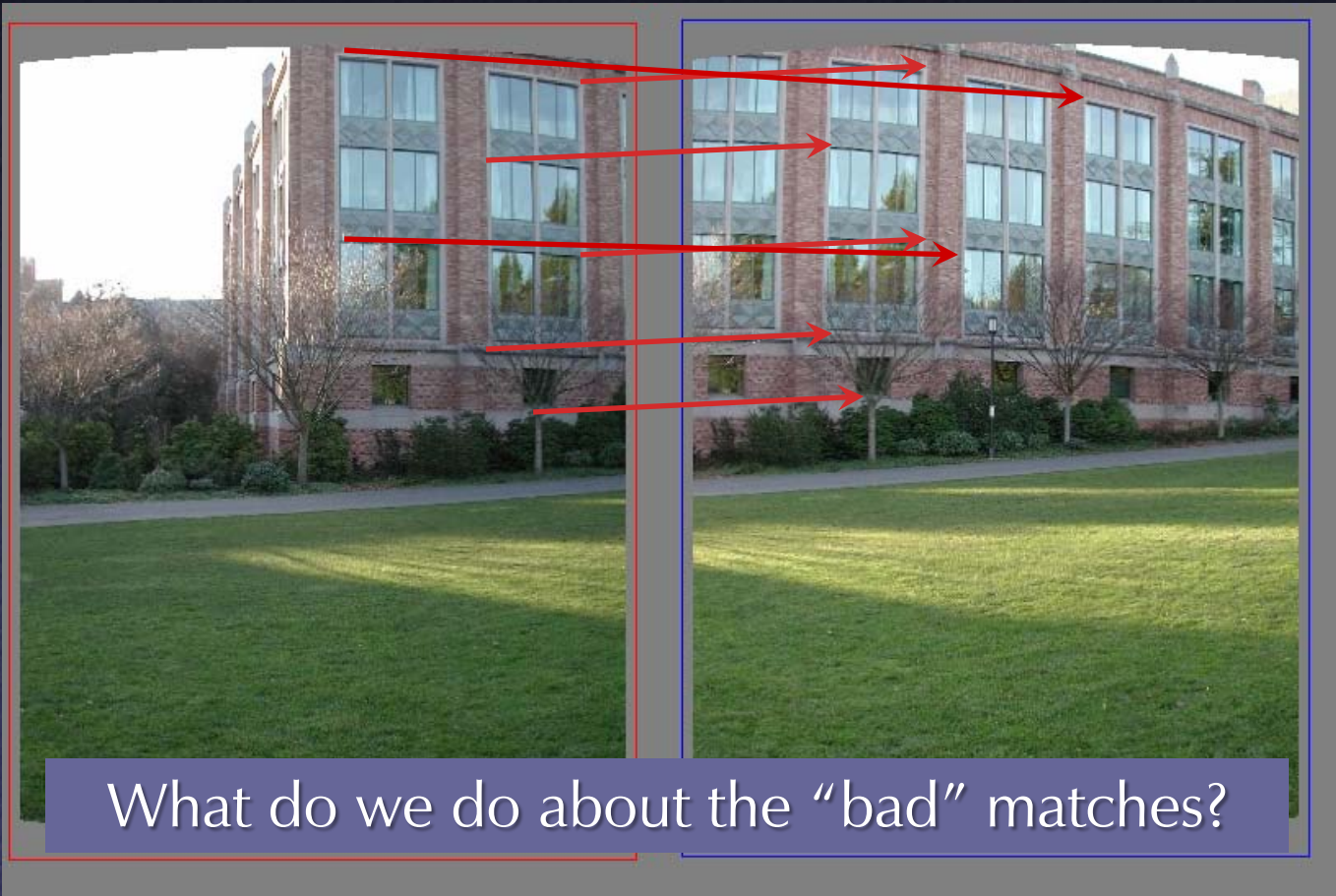
Idea: Represent $N \times N$ image as a “pyramid” of $1 \times 1, 2 \times 2, 4 \times 4, \dots, 2^k \times 2^k$ images (assuming $N = 2^k$)



Correspondence Approaches

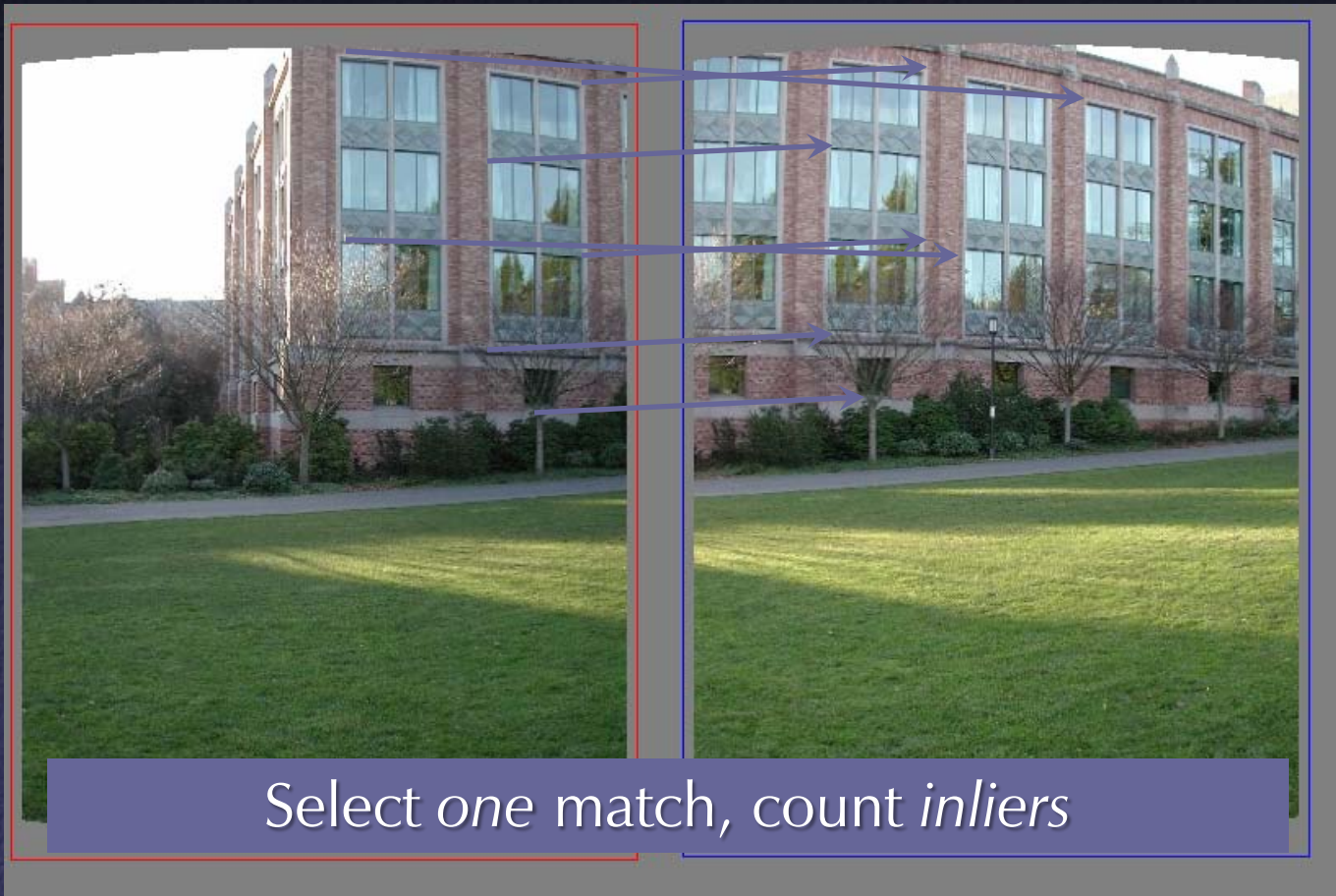
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Matching features

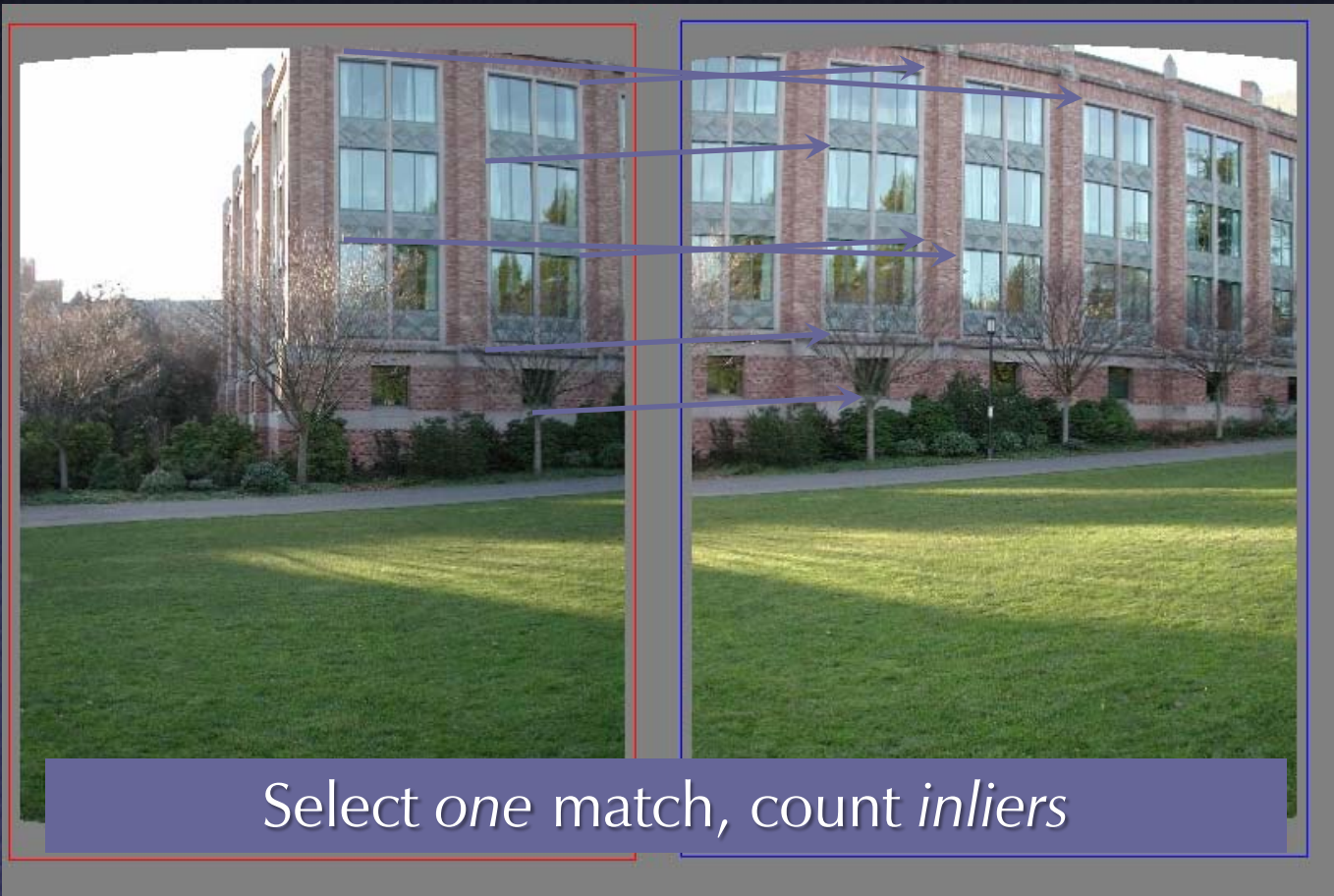


What do we do about the "bad" matches?

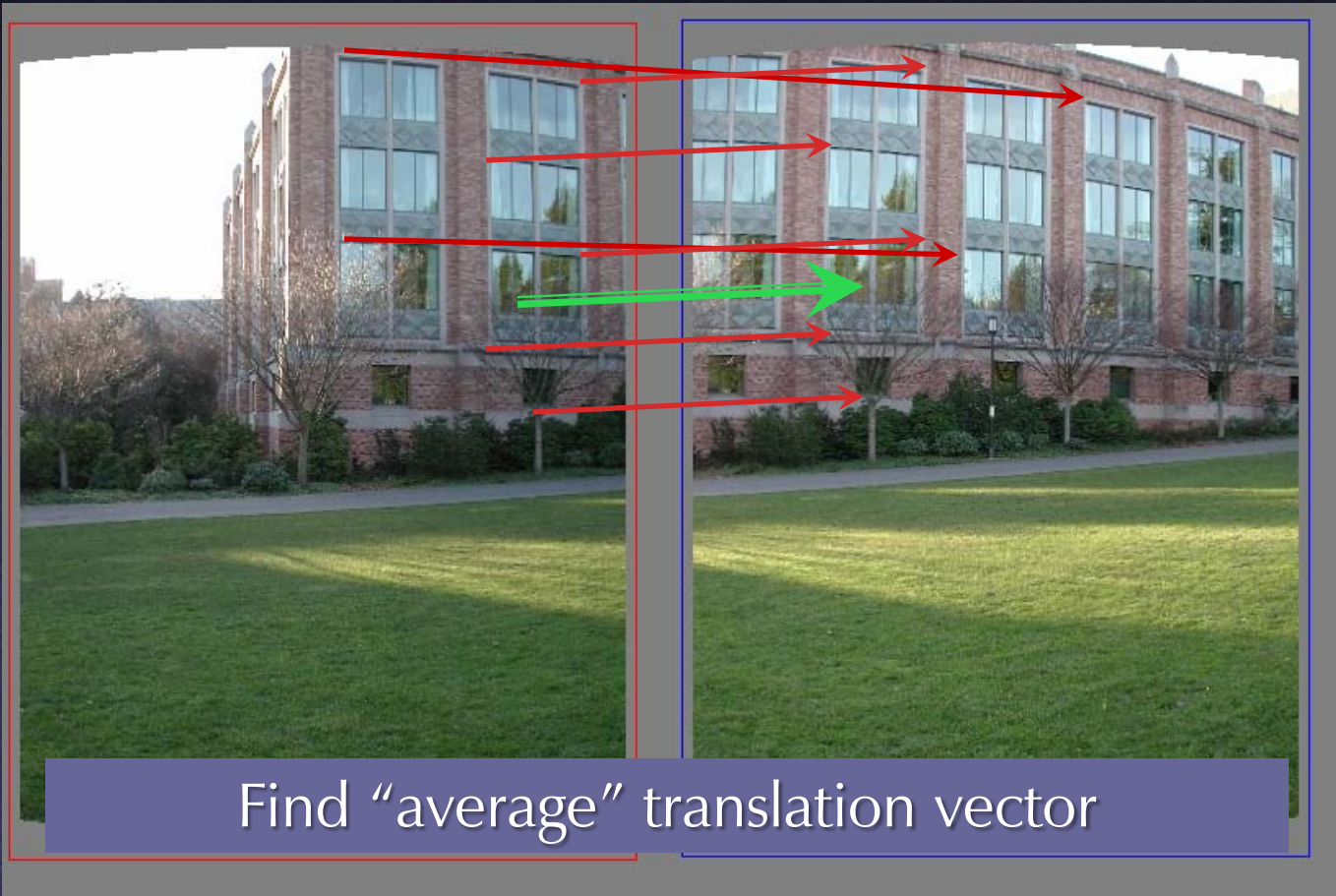
Random Sample Consensus



Random Sample Consensus



Least squares fit



Panoramic Mosaicing

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2. Merge overlapping regions



Blending

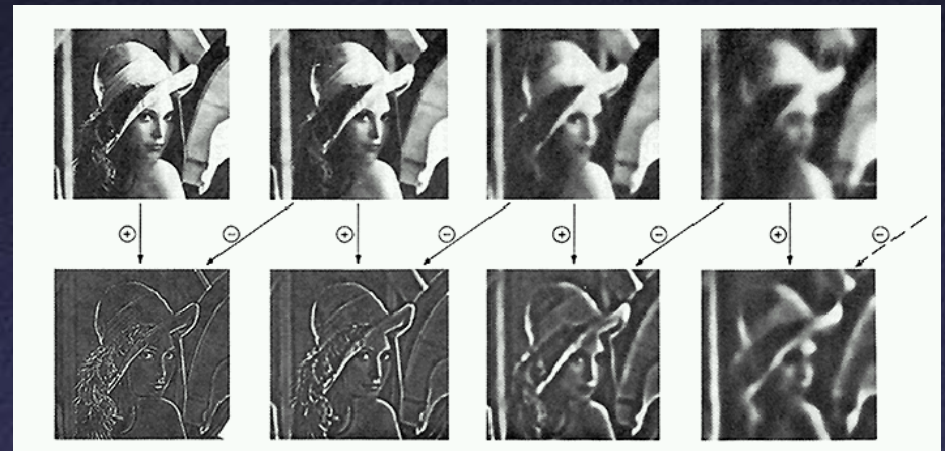
- Blend over too small a region: seams
- Blend over too large a region: ghosting

Multiresolution Blending

- Different blending regions for different levels in a pyramid [Burt & Adelson]
 - Blend low frequencies over large regions (minimize seams due to brightness variations)
 - Blend high frequencies over small regions (minimize ghosting)

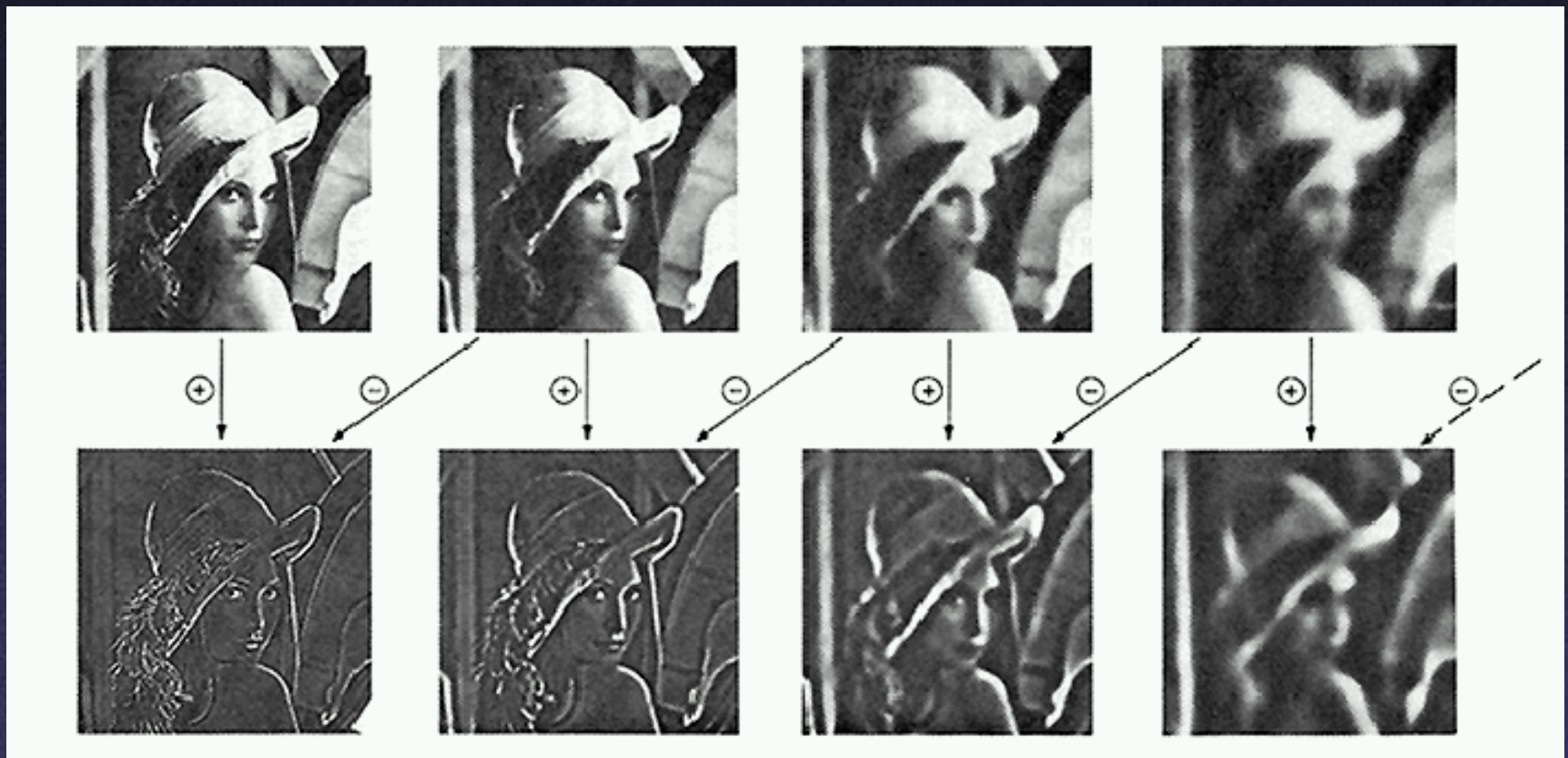
Pyramid Creation

- “Gaussian” Pyramid
 - “Laplacian” Pyramid
 - Created from Gaussian pyramid by subtraction
- $$L_i = G_i - \text{expand}(G_{i+1})$$



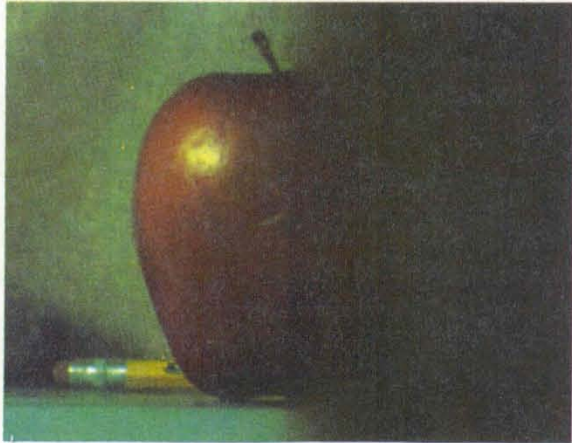
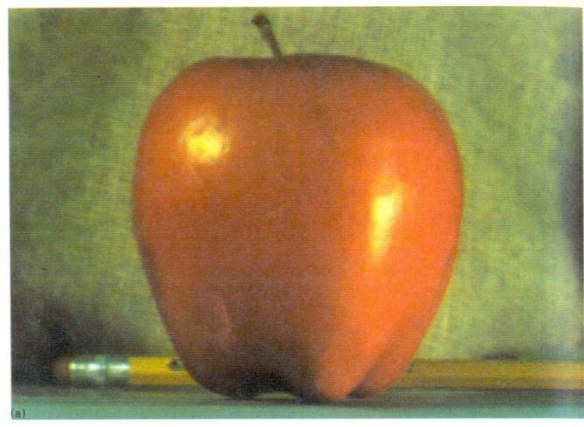
Octaves in the Spatial Domain

Lowpass Images

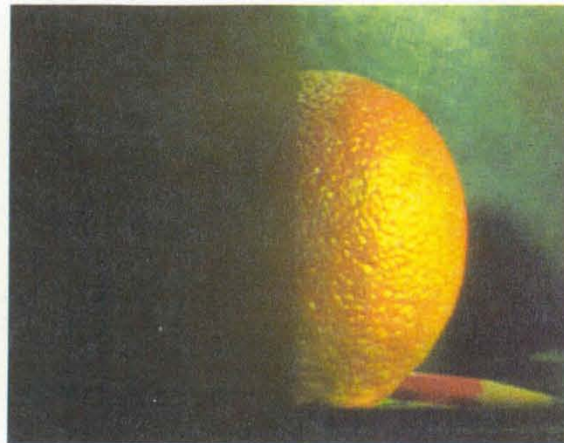


Bandpass Images

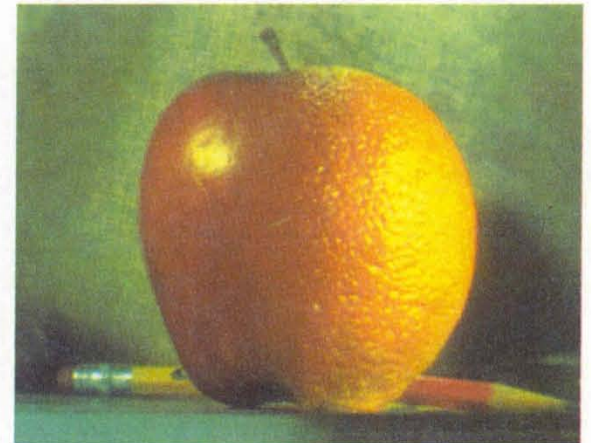
Pyramid Blending



(d)



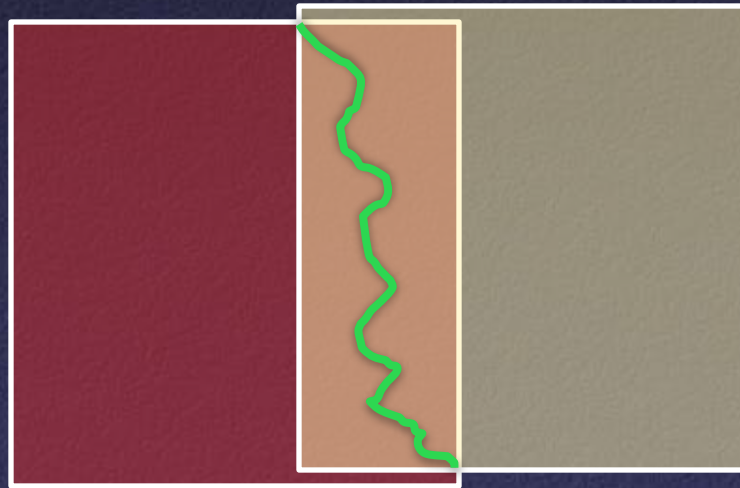
(h)



(l)

Minimum-Cost Cuts

- Instead of blending high frequencies along a straight line, blend along line of minimum differences in image intensities



Minimum-Cost Cuts



Moving object, simple blending → blur

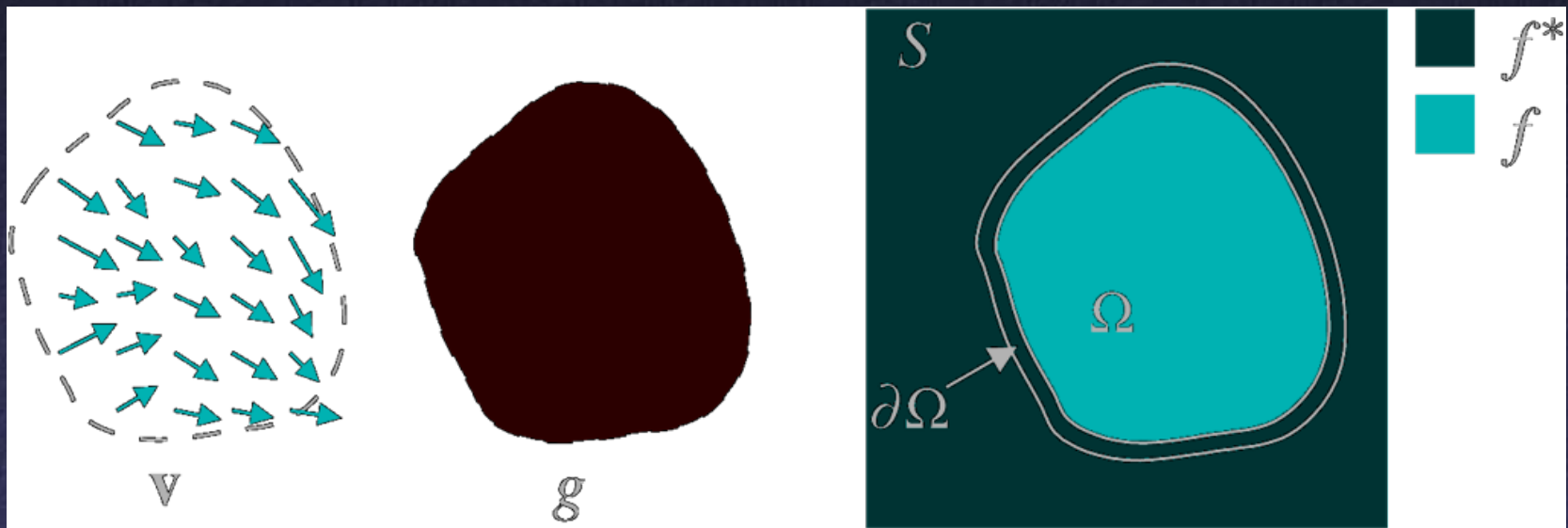
Minimum-Cost Cuts



Minimum-cost cut → no blur

Poisson Image Blending

- Follow gradients of source subject to boundary conditions imposed by dest

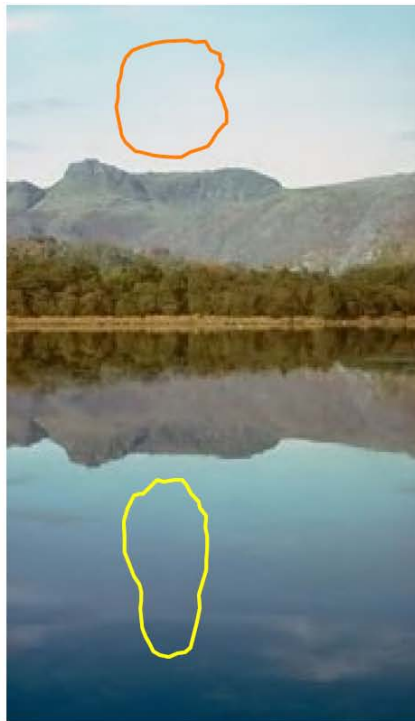


$$\begin{cases} \nabla^2 f = \nabla \cdot \mathbf{v} \\ f|_{\partial\Omega} = f^*|_{\partial\Omega} \end{cases}$$

Poisson Image Blending



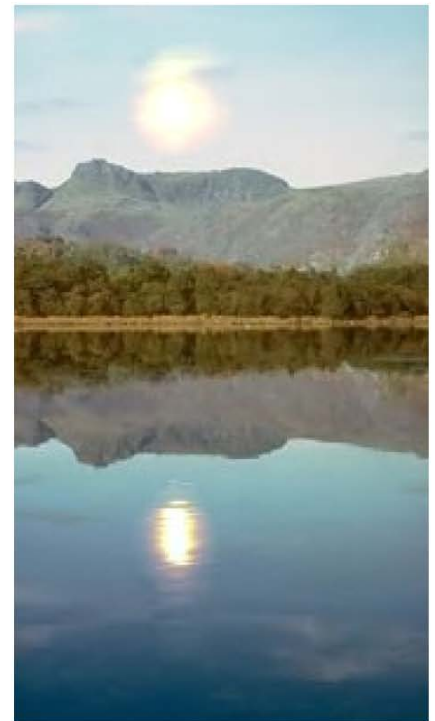
sources



destinations



cloning



seamless cloning

Poisson Image Blending



source/destination



cloning



seamless cloning