Seam Carving: How to "Rescale" Pictures

Changing Image Size

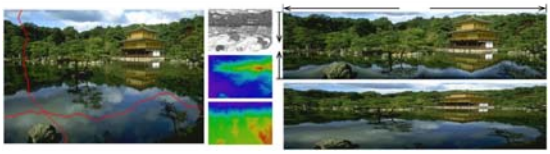
...while keeping content intact

- problem: target many devices
- scaling? cropping? seam carving!

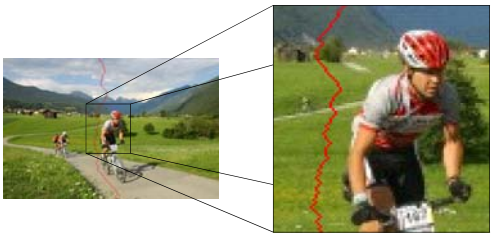
Basic Idea

Remove inconspicuous pixels

- one pixel from each (and every) row (or column)

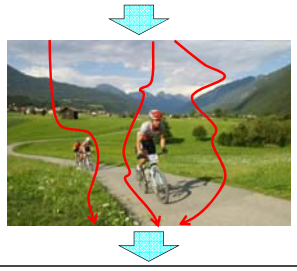


Seams in Action



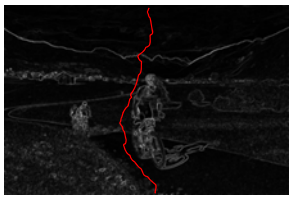
Seams in Action

Finding the Seam?



The Optimal Seam

$$E(I) = |\partial_x I| + |\partial_y I| \qquad E(s^*) = \min_s E(s)$$



Optimal Path

What is a valid path?

- monotonic, continuous
- cost is evaluated per pixel
  - e.g., centered difference
  - other cost measures…
- find by dynamic programming
  - optimal substructure…
  - lots over overlapping sub problems

Construction

Top to bottom (for vertical seams)

- from second to last row

5	8	9	3
9	2	3	9
7	3	4	2
4	5	7	8

$$M(i,j) = e(i,j) + \min(M(i-1,j-1), M(i-1,j), M(i-1,j+1))$$

Typical Seams

Image Enlargement

Run “in reverse”

- insert seams as interpolants of neighbors by increasing energy

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Both Dimensions

Retargeting horizly. and vertly.

- what order for given size?
- dynamic programming again

$$T(r,c) = \min(\quad T(r-1,c) + E(s^x(I_{n-r-1,m-c})),$$
$$T(r,c-1) + E(s^y(I_{n-r,m-c-1})))$$

- binary array of decisions

Object Removal

Additional weighting possible

- lower or higher energy on demand

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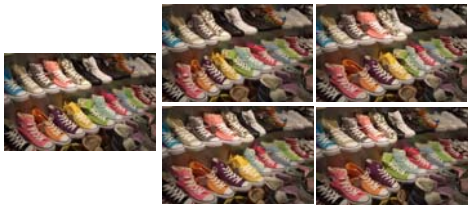
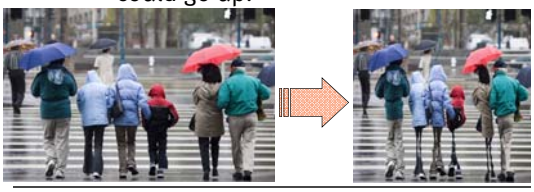


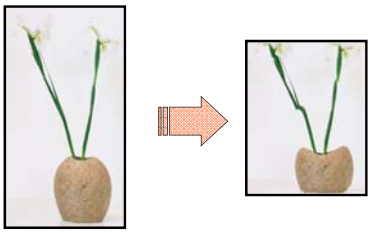
Refinements

Forward and backward energy

- energy after removing seam?
  - could go up!



Artifacts



Changes in Image

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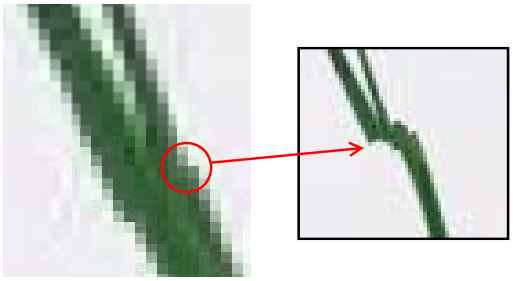
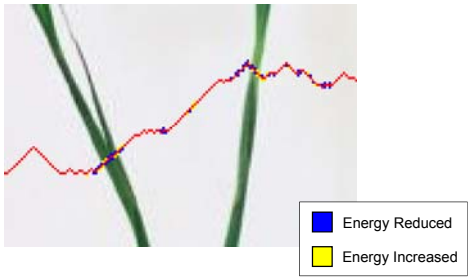
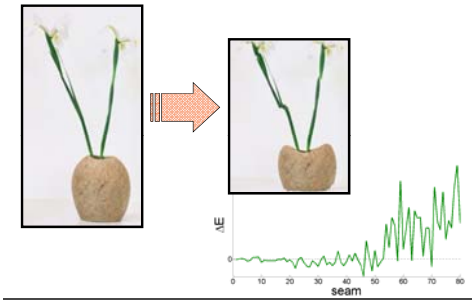


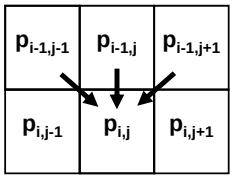
Energy Inserted/Removed



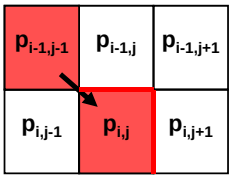
Changes in Energy



Tracking Energy

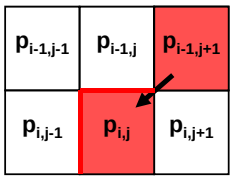


Pixel $P_{I,J}$: Left Seam



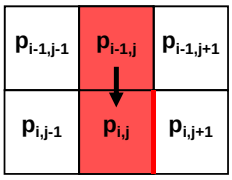
$$C_L(i,j) = |I(i,j+1) - I(i,j-1)| + |I(i-1,j) - I(i,j-1)|$$

Pixel $P_{I,J}$: Right Seam



$$C_R(i,j) = |I(i,j+1) - I(i,j-1)| + |I(i-1,j) - I(i,j+1)|$$

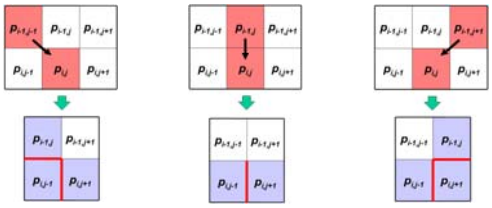
Pixel $P_{I,J}$: Vert. Seam



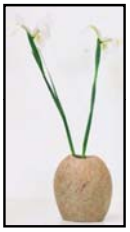
$$C_V(i,j) = |I(i,j+1) - I(i,j-1)|$$

New Energy Function

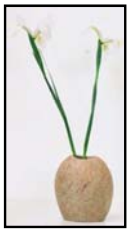
$$M(i,j) = P(i,j) + \min \begin{cases} M(i-1,j-1) \\ M(i-1,j) \\ M(i-1,j+1) \end{cases}$$

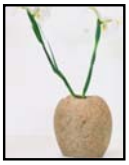


Backward (SIG 07)



Forward (SIG 08)





Backward

Forward

Backward

Forward

Backward Expand

Forward Expand

As Graph Cut Problem

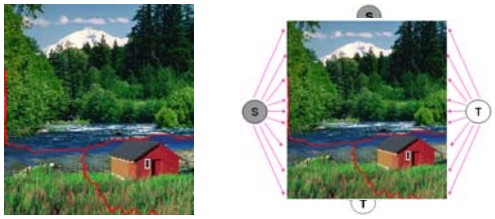
Motivated by video…

- set up graph so that optimal seam is optimal cut of graph $O(VE^2)$
  - or LP
- expensive…
  - need other tricks to make practical
- we'll ignore that for now

Challenge

How to Define a Seam from a Cut?

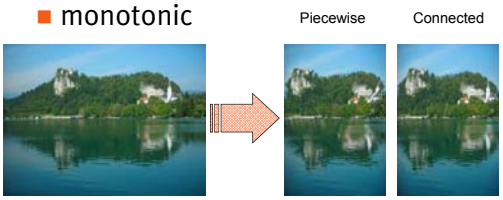
Kwatra et al. Siggraph 2003, *Graph cut textures*



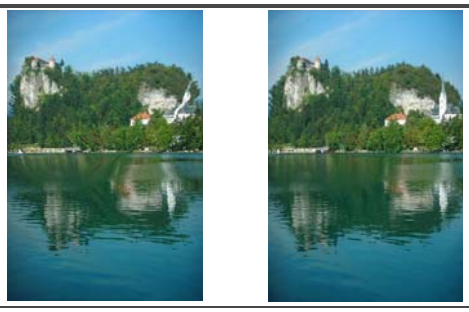
Constraints

Seams need to be…

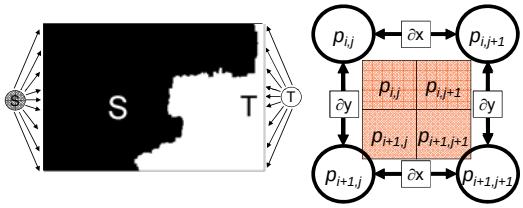
- connected
- monotonic



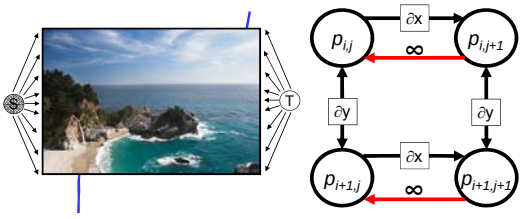
Piecewise vs. Connected



Standard Construction



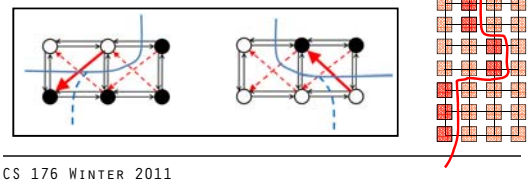
Monotonicity



Seam from Cut

Conditions

- monotonic
- connected



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