Seam Carving:
How to "Rescale" Pictures

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Changing Image Size

...while keeping content intact
- problem: target many devices
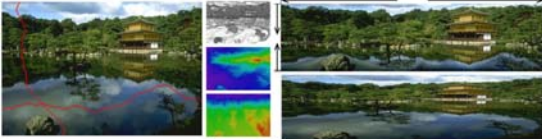- scaling? cropping? seam carving!

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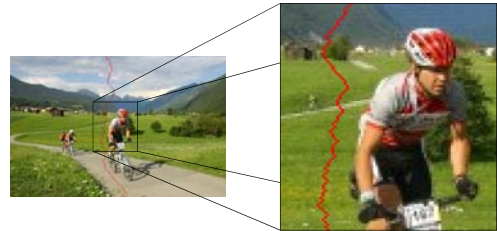
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Basic Idea

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

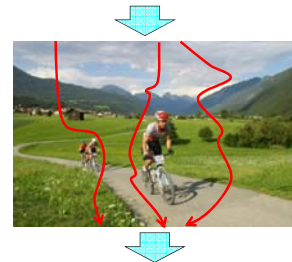CS 176 Winter 2011

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Seams in Action

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Seams in Action
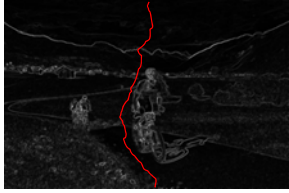

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Finding the Seam?

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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

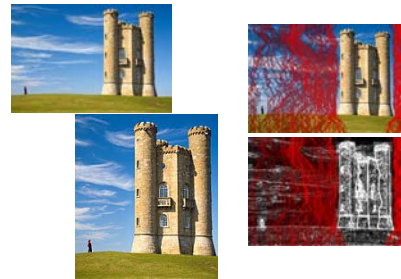Top to bottom (for vertical seams)
- from second to last row

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

Image Enlargement

Run "in reverse"
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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

Object Removal
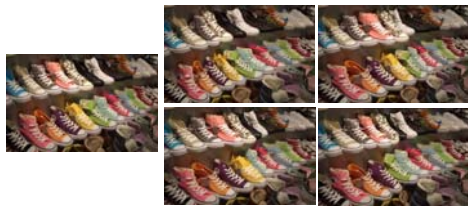
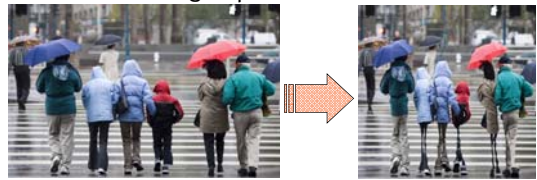Additional weighting possible
- lower or higher energy on demand

Refinements

Forward and backward energy
- energy after removing seam?
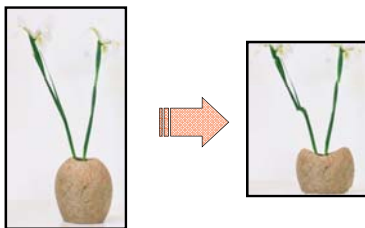 - could go up!

Artifacts
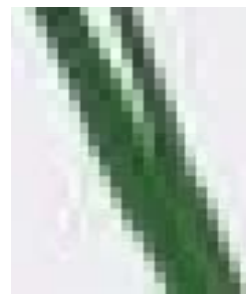
Changes in Image

CHANGES IN IMAGE

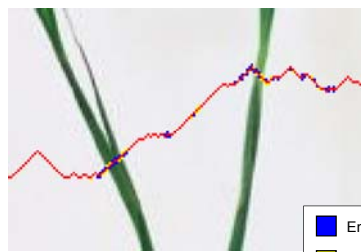CS 176 WINTER 2011

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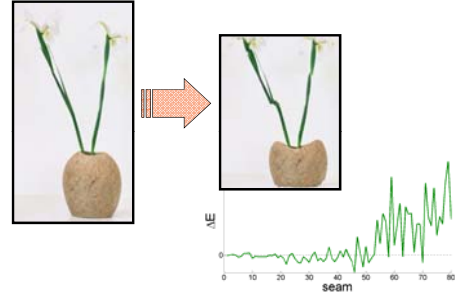# CHANGES IN IMAGE

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ENERGY INSERTED/REMOVED

■ Energy Reduced
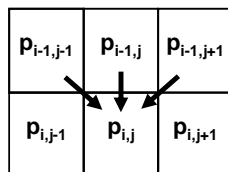■ Energy Increased

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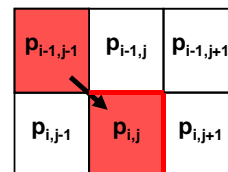
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CHANGES IN ENERGY

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TRACKING ENERGY

$p_{i-1,j-1}$	$p_{i-1,j}$	$p_{i-1,j+1}$
$p_{i,j-1}$	$p_{i,j}$	$p_{i,j+1}$

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PIXEL $P_{I,J}$: LEFT SEAM

$p_{i-1,j-1}$	$p_{i-1,j}$	$p_{i-1,j+1}$
$p_{i,j-1}$	$p_{i,j}$	$p_{i,j+1}$

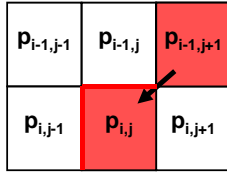$$C_L(i,j) = |I(i,j+1) - I(i,j-1)| + |I(i-1,j) - I(i,j-1)|$$
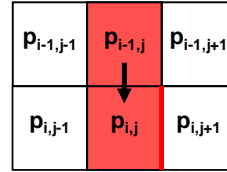
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PIXEL P$_{I,J}$: RIGHT SEAM

| p$_{i-1,j-1}$ | p$_{i-1,j}$ | p$_{i-1,j+1}$ |
| p$_{i,j-1}$ | p$_{i,j}$ | p$_{i,j+1}$ |

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

PIXEL P$_{I,J}$: VERT. SEAM

| p$_{i-1,j-1}$ | p$_{i-1,j}$ | p$_{i-1,j+1}$ |
| p$_{i,j-1}$ | p$_{i,j}$ | p$_{i,j+1}$ |

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

NEW ENERGY FUNCTION

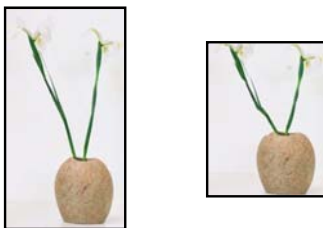$$M(i,j) = P(i,j) + \min \begin{cases} M(t-1, j-1) \\ M(i-1, j) \\ M(i-1, j+1) \end{cases}$$
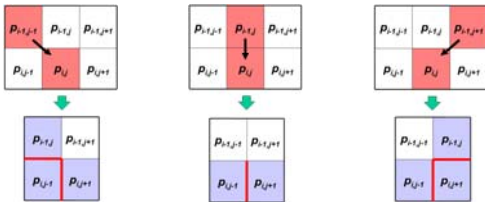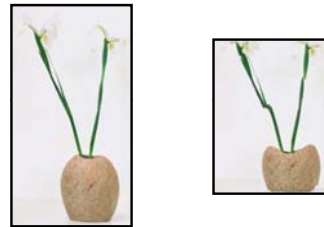
BACKWARD (SIG 07)

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…
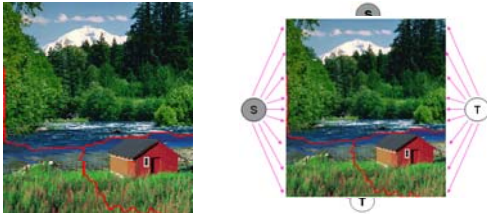 - need other tricks to make practical
- we'll ignore that for now

CHALLENGE

How to Define a Seam from a Cut?
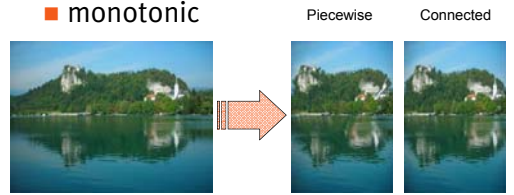
Kwatra et al. Siggraph 2003, *Graph cut textures*

CONSTRAINTS

Seams need to be…
- connected
- monotonic

Piecewise   Connected

PIECEWISE VS. CONNECTED

STANDARD CONSTRUCTION

MONOTONICITY

SEAM FROM CUT

Conditions
- monotonic
- connected

Seam from Cut

Conditions
- monotonic
- connected