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

Finding the Seam?
THE OPTIMAL SEAM

\[ E(I) = |\partial_x I| + |\partial_y I| \quad E(s^*) = \min_{s} E(s) \]

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

\[
\begin{array}{cccc}
5 & 8 & 9 & 3 \\
9 & 2 & 3 & 9 \\
7 & 3 & 4 & 2 \\
4 & 5 & 7 & 8 \\
\end{array}
\]

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

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
  \[ T(r,c) = \min \left( T(r-1,c) + E(s^r(I_{n-r+1,m-c})), \right. \]
  \[ \left. T(r,c-1) + E(s^c(I_{n-r,m-c-1})) \right) \]
- 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
Changes in Image

Energy Inserted/Removed

Tracking Energy

Pixel $P_{1,j}:$ Left Seam

Energy Reduced
Energy Increased

$C_{L}(i,j) = |I(i,j+1) - I(i,j-1)| + |I(i-1,j) - I(i,j+1)|$
**Pixel $P_{i,j}$: Right Seam**

$C_w(i,j) = |F(i, j + 1) - F(i, j - 1)| + |F(i - 1, j) - F(i, j + 1)|$

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**Pixel $P_{i,j}$: Vert. Seam**

$C_v(i,j) = |F(i, j + 1) - F(i, j - 1)|$

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**New Energy Function**

$M(i,j) = P(i,j) = \min \left\{ \begin{array}{c} M(i - 1, j - 1) \\ M(i - 1, j) \\ M(i, j - 1) \\ M(i, j) \\ M(i + 1, j) \\ M(i, j + 1) \end{array} \right\}$

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**Backward (SIG 07)**

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**Forward (SIG 08)**

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**Backward**
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

CONSTRUCTIONS

Seam from Cut
Conditions
- monotonic
- connected
Seam from Cut

Conditions
- monotonic
- connected